Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

FINAL REPORT

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2019 Load Impact Evaluation for San Diego Gas and Electric's Small Commercial and Agricultural Critical Peak Pricing and Commercial Technology Deployment Program

Prepared for SD&GE
By Demand Side Analytics, LLC
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ABSTRACT

This study quantifies the demand impacts of three related interventions – time of use pricing with a critical peak pricing component, the shift in a time of use pricing window, and commercial thermostats. The study focuses on three primary research questions: What were the 2019 demand reductions due to dispatch operations? Are customers delivering non-dispatchable demand reductions due to the interventions? What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

SDG&E transitioned the full population of approximately 120,000 small business and agricultural customers from rates that did not vary by time of day to time varying rates in 2016. As part of the transition, in 2017 and part of 2018, SDG&E offered customers smart thermostats, free of charge, to help them manage their energy bills and automate response to critical peak prices. After the transition was complete the program was transitioned to a rebate model and split by customers on dispatchable rates Peak Shift at Work (PSW) and Critical Peak Pricing – Default (CPP-D) for medium commercial and Industrial customers versus those that aren't AC Saver Day Ahead, (ACSDA). Dispatchable demand reductions were analyzed separately from non-dispatchable energy savings and demand reductions. In 2019 there were no dispatchable critical peak pricing events called for small non-residential customers or for commercial thermostats with critical peak pricing. However, several events were called for the AC Saver Day Ahead program. The 0.52 MW delivered by the thermostats on AC Saver Day Ahead came from the roughly 50% of devices still connected in PY 2019. ACSDA devices were typically dispatched between 6 and 8 pm.

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1 EXECUTIVE SUMMARY

Between November 2015 and April 2016, SDG&E defaulted over 120,000 small business customers from rates that did not vary by time of day onto time varying pricing with a critical peak pricing component (CPP-TOU) If these customers did not want critical peak pricing, they had the option to elect a time-of-use rate (TOU) without a critical peak component. Approximately 95% of customer sites remained on TOU-CPP rate and 5% elected the TOU only option. In tandem, SDG&E also transitioned small agricultural customers from rates that did not vary by time of day onto default time of use rates. A CPP-TOU rate was offered to customers on a voluntary (opt-in) basis. By April 2016, electricity rates without a time varying component were no longer available for small commercial and agricultural customers. Leading up to and after the rate transition, SDG&E offered customers smart thermostats, free of charge, to help them manage their energy bills and automate response to critical peak prices. This commercial thermostat program has now transitioned to a rebate model and has been separated into two program types: one for sites on dispatchable (CPP) rates and ones that are not.

The study analyzes three different interventions – TOU-CPP events for small non-residential sites, the shift of TOU peak window for small non-residential sites, and critical peak events for commercial thermostats –and focuses on three primary research questions:

- What were the 2019 demand reductions due to dispatch operations?
- What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

Table 1 summarizes the estimated demand reductions for each of the interventions and distinguishes between dispatchable and non-dispatchable resources. Note that while load impacts for the TOU peak shift were substantial, results suggest that the impact may fade somewhat over time, highlighting the potential importance of periodic customer communications about peak periods.

Table 1: Summary of 2019 Average Demand Reductions

Technology Intervention	Sites	Load without DR (MW)	Load reduction (MW)	% Reduction
Tech Deployment: ACSDA (6-8 pm, average event)	1,452	18.75	0.52	2.8%

Table 2 summarizes the small CPP and commercial thermostat dispatchable ex ante reductions under August monthly peaking conditions for a 1-in-2 weather year[1]. The results are shown under both CAISO and SDG&E peaking conditions and reflect the reduction capability from 4-9 pm, which aligns with resource adequacy requirements. For small CPP, the dispatchable reductions decrease due to projected decreases in enrollment. Over time, customers are expected to sort themselves between TOU-CPP and TOU rates. Despite new installations projected for commercial thermostats, ex ante impacts for commercial thermostats are also expected to decrease given that thermostat connection rates decline over time faster than new thermostats are projected to be added.

While no events were called in PY 2019 for small CPP and commercial thermostat customers on CPP rates they have historically been dispatched during the 2 to 6pm event window. Commercial thermostat customers on ACSDA were called during different events and later in the day, typically from 6 to 8 pm. Across the eighteen ACSDA events dispatched in PY 2019 only eight were called on days with maximum temperatures above 88 degrees and several were called on days much cooler than that. Hourly temperature during twelve events were below 75 degrees when there is far less cooling load available to be curtailed. As a result, ex post impacts per thermostat have historically been much lower for ACSDA than for commercial thermostats on dispatchable rates. However, ex ante impacts per thermostat and per site, as shown in Table 2, are higher for ACSDA than for CPP-TD. This is primarily because CPP-TD, as a dispatchable rate with a fixed window, is assumed to deliver impacts only during the 2pm to 6pm critical peak window, which only has two hours of overlap with the 4pm to 9pm resource adequacy window. In contrast, the ACSDA program can be dispatched any time between 1pm and 9pm. As such, the ACSDA ex ante impacts assume reductions are delivered for the full duration of the 4pm to 9pm resource adequacy window.

Table 2: Summary of Ex ante Dispatchable Demand Reductions

Year	Small CPP			Tech Deployment: CPP rates			Tech Deployment: ACSDA		
	Sites	MW (CAISO)	MW (SDG&E)	Sites	MW (CAISO)	MW (SDG&E)	Sites	MW (CAISO)	MW (SDG&E)
2019	111,149	1.97	1.97	1,744	0.32	0.30	1,524	0.77	0.75
2020	107,603	1.91	1.91	1,677	0.24	0.23	1,592	0.90	0.87
2021	104,170	1.85	1.85	1,611	0.17	0.16	1,660	1.01	0.98
2022	100,846	1.79	1.79	1,544	0.11	0.11	1,728	1.10	1.07
2023	97,629	1.73	1.73	1,544	0.08	0.08	1,728	0.93	0.90
2024	94,514	1.67	1.68	1,544	0.06	0.05	1,728	0.78	0.76
2025	91,498	1.62	1.63	1,544	0.04	0.03	1,728	0.66	0.64
2026	88,579	1.57	1.57	1,544	0.02	0.02	1,728	0.55	0.54

[1] Though no CPP events were called in PY 2019, ex ante estimates for dispatchable rates were developed using impacts from previous years, updated to reflect PY 2019 enrollment forecasts and device connectivity

Year	Small CPP			Tech Deployment: CPP rates			Tech Deployment: ACSDA		
	Sites	MW (CAISO)	MW (SDG&E)	Sites	MW (CAISO)	MW (SDG&E)	Sites	MW (CAISO)	MW (SDG&E)
2027	85,753	1.52	1.52	1,544	0.01	0.00	1,728	0.47	0.45
2028	83,017	1.47	1.47	1,544	0.00	0.00	1,728	0.39	0.38
2029	80,369	1.42	1.43	1,544	0.00	0.00	1,728	0.33	0.32
2030	77,806	1.56	1.50	1,544	0.00	0.00	1,728	0.28	0.27

2 INTRODUCTION

Most small business (SMB) customers across the U.S. have the same price throughout the day and do not have an incentive to consider the timing of their energy consumption and the degree to which consumption during peak hours drives energy and infrastructure costs. Between November 2015 and April 2016, SDG&E transitioned over 120,000 small business customers onto time of use rates with a critical peak component (CPP-TOU). While customers were defaulted onto TOU-CPP rates, they could elect to opt-out to a time-of-use (TOU) rate and 5% of them did. As of PY 2019, about 112,000 sites remain on the CPP-TOU rate, implying a three year opt-out rate of about 7%, which is relatively stable relative to the initial 5% opt-out rate. In tandem, SDG&E also transitioned small agricultural customers from flat rates onto time of use rates and offered a CPP-TOU rate on a voluntary (opt-in) basis. By April 2016, electricity rates without a time varying component were no longer available for small commercial and agricultural customers. In the years leading up to and after the rate transition, SDG&E offered customers smart thermostats, free of charge, to help them manage their energy bills and automate response to critical peak prices.

The transition to time varying rates encourages customers to consider when they consume power in addition to how much they consume. Customers can save by modifying when they use energy and by reducing energy use. The rates also better align the prices customers face and with the cost of supplying power. Prior to the transition, SDG&E implemented an outreach and education campaign designed to increase awareness and improve understanding of the new rate.

2.1 RATE AND TECHNOLOGIES EVALUATED

A total of three related but distinct interventions were assessed as part of the evaluation:

- CPP-TOU – Critical peak prices are designed to incentivize customers to reduce or shift electricity use from peak hours on a handful of days that drive the need for building additional power infrastructure. Customers receive rate reductions during summer non-event days to offset the higher prices during critical peak events (less than 1% of hours). At SDG&E, the CPP rates are layered on top of TOU rates. Historically, the event window was 11am to 6pm but beginning in 2018 the window was narrowed to 2 to 6pm.

- Smart thermostats – Through 2017, customers undergoing the transition to time varying rates were eligible for free Ecobee thermostats to help automated price response during critical peak periods. The thermostats also can help reduce electricity consumption when a business is unoccupied. After the 2017 event season the program was shifted to a rebate design and expanded to allow additional

thermostat models.[2] There are four Technology Deployment programs of which some variants have been in operation since 2014[3]. Prior to 2017, customers were not required to be on a CPP rate, customers on TOU only rates are in the AC Saver Day Ahead (ACSDA) programs—one for non-residential customers and one for quasi-residential customers. Historically, all thermostats were dispatched from 2 to 6pm on CPP event days. Beginning in 2018, ACSDA events were called separately and did not necessarily overlap with CPP event days. ACSDA thermostats can be dispatched at any time between 12 pm to 9 pm (on-peak hours) for a maximum of 4 consecutive hours and most events in 2018 were called from 6-8pm. For Technology Deployment customers on CPP rates (CPPTD) thermostats are still dispatched from 2-6pm on CPP event days. The two rate-based programs are Peak Shift at Work (PSW, for small commercial customers) and CPP-D (for medium and large commercial customers). Both CPP and ACSDA devices are curtailed by raising the thermostat temperature set point 4 degrees during the event window.

Both the CPP-TOU and TOU rates provide customers an incentive to reduce or shift electricity use away from peak hours. The CPP-TOU rates include higher prices during critical peak events, an event adder, which is applicable to usage during critical peak events which can be called between the hours of 2 pm and 6 pm during the summer.

2.2 STUDY RESEARCH QUESTIONS

Table 3 summarizes the key research questions for each intervention. Both CPP-TOU and commercial thermostats are dispatchable resources that also can lead to daily changes in energy use. Because dispatchable resources are used for operations, the impacts associated with event dispatch are estimated and reported separately from daily, non-dispatchable changes in energy use.

Table 3: Key Research Questions

	Research Question	TOU	CPP-TOU	SCTD
1	What were the demand reductions due to program operations and interventions in 2019 – for each event day and hour?		✓	✓
2	How do load impacts differ for customers who have enabling technology and/or are dually enrolled in other programs?		✓	✓

[2] SDG&E had a limited number of free thermostats available in 2018 that were provided on first serve basis, the remainder of the 2018 thermostats were purchased by the customer and rebates were issued.
[3] Expanded from the former Small Commercial Technology Deployment (SCTD) program

	Research Question	TOU	CPP-TOU	SCTD
3	How does weather influence the magnitude of demand response?	✓	✓	✓
4	How do load impacts vary for different customer sizes, locations, and customer segments?	✓	✓	✓
5	What is the ex ante load reduction capability for 1-in-2 and 1-in-10 weather conditions? And how well does it align with ex post results and prior ex ante forecasts?		✓	✓
6	What concrete steps or experimental tests can be undertaken to improve program performance?		✓	✓

2.3 OVERVIEW OF METHODS

The primary challenge of impact evaluation is the need to accurately detect changes in energy consumption while systematically eliminating plausible alternative explanations for those changes, including random chance. Did the introduction of time varying rates or smart learning thermostats cause a change in critical peak period demand? Or can the differences be explained by other factors? To estimate energy savings, it is necessary to estimate what energy consumption would have been in the absence of the intervention—the counterfactual or reference load.

The change in energy use patterns was estimated using a panel regression with multiple control groups, each matched to a participant. Key modeling design components are as follows:

- **Multiple matched controls:** For each participant, five control sites were identified based on how closely their loads matched the participant on event-like proxy days (e.g. using Euclidian distance matching). A total of five matched control sites were selected for each participant site, ranked by their closeness of fit across all proxy days.
- **Panel regression model with event and non-event day and participants and matched controls:** The data was structured as a time series for each participant. The control loads, weather, and day characteristics were used to predict participant loads. The model coefficients for each control site essentially weight the various control sites based on their predictive power creating a more accurate prediction out of multiple controls. This approach was used as the primary method for event impacts for critical peak events delivered by AC Saver Day Ahead thermostat participants.
- **Event specific models:** Given the wide range of temperature conditions during events, five proxy days were selected for each event based on the how closely the proxy day conditions, measured by system load, matched the event days (e.g. using Euclidean distance matching). A separate model was estimated for each event including only loads for the

event day and the proxy days selected for that event. The number of proxy days included was validated using the model validation process described below.

- **Pre and post event adjustment:** The impact regression also included pre and post event loads to adjust the model for differences. A two hour pre- and post-adjustment period with a two hour pre- and post-buffer was used. Inclusion of these parameters was validated using the model validation process described below.
- **Model validation:** The choice of the number of proxy days (ranging from two to five), of the number of matched control sites (ranging from one to five), and of the inclusion of pre and post event adjustment parameters was validated using a placebo effect approach: a subset of proxy days was used to predict load on the remaining proxy days for each event. In the absence of events, the difference between predicted and actual error should be zero and any deviation is a direct reflection of modeling error. In each case the approach with the least error and best fit was selected.

Figure 1 summarizes the out of sample testing process used to select the number of proxy days, controls, and adjustments to be used for modeling. Essentially, the out of sample process is an iterative approach whereby data is systematically left out of the matching model then used to assess model performance—a well performing model should produce matches for loads on days which were not used for the model. The final model is identified based on least bias (% Bias) and best fit (Relative RMSE) metrics. As an example, Figure 2 summarizes the model selection analysis for the non-residential ACSDA programs. Each row shows a different adjustment model and each cluster of bars shows results for a selected number of proxy days. Each individual bar in a cluster shows results for a selected number of control sites per participant site. Note that across the 60 models tested, the one with the best precision (lowest RMSE) is the one with a pre and post adjustment, using five proxy days and five control sites. This is the model that was selected for estimating counterfactual loads during events. Using multiple proxy days, matched controls and, adjustments systematically increased model precision though there are diminishing returns to including additional proxy days and matched controls.

Figure 1: Out of Sample Process for Model Selection

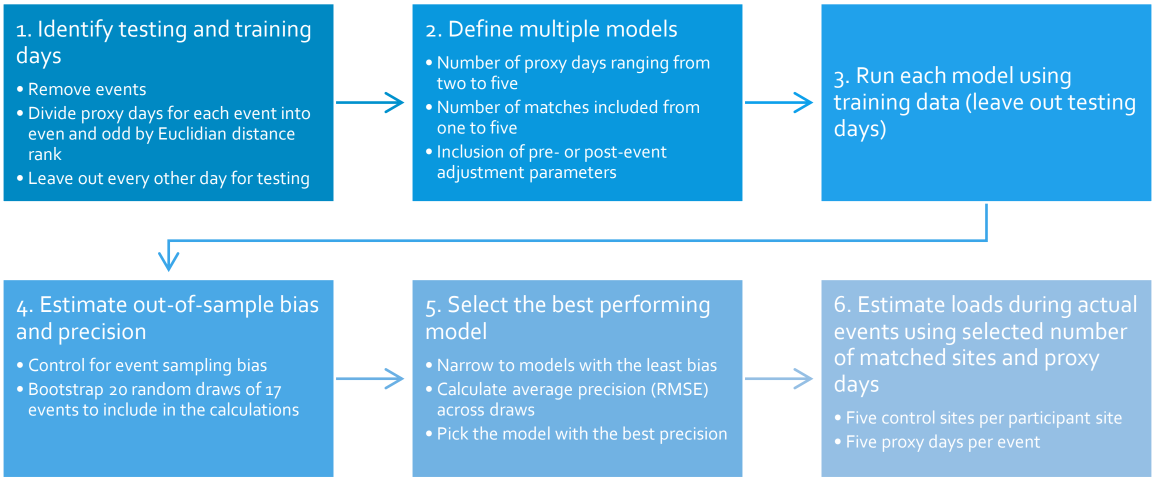


Figure 2: Model Selection Results

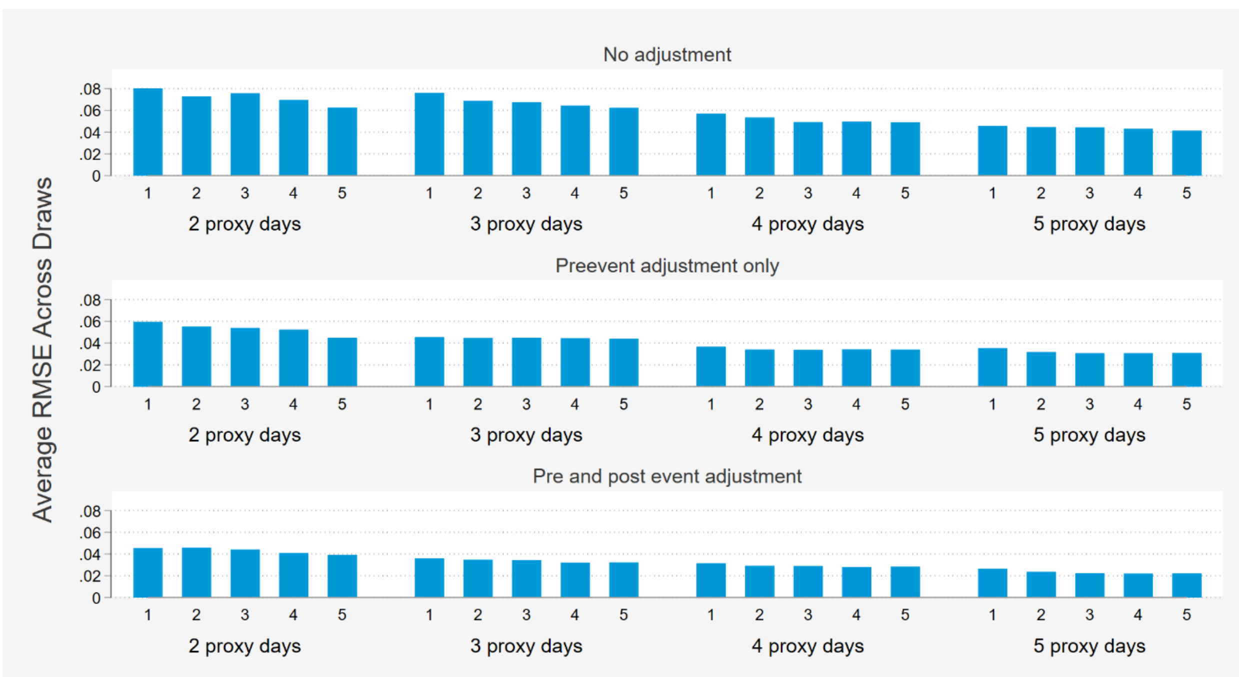


Table 4 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments equaled the sum of the parts. Because impacts for each segment were added together, the segmentation was structured to be mutually exclusive and completely exhaustive. In other words, every customer was assigned to exactly one segment. By design, the segmentation differentiated customers who were expected to deliver demand reductions– such as customers who sign up for event notification or technology to automate response – from customers who were expected to deliver little or no demand reductions. Additional segments were analyzed, after the fact, as part of exploratory analysis, but the core results presented are based on the segmentation detailed below.

Table 4: Evaluation Methods

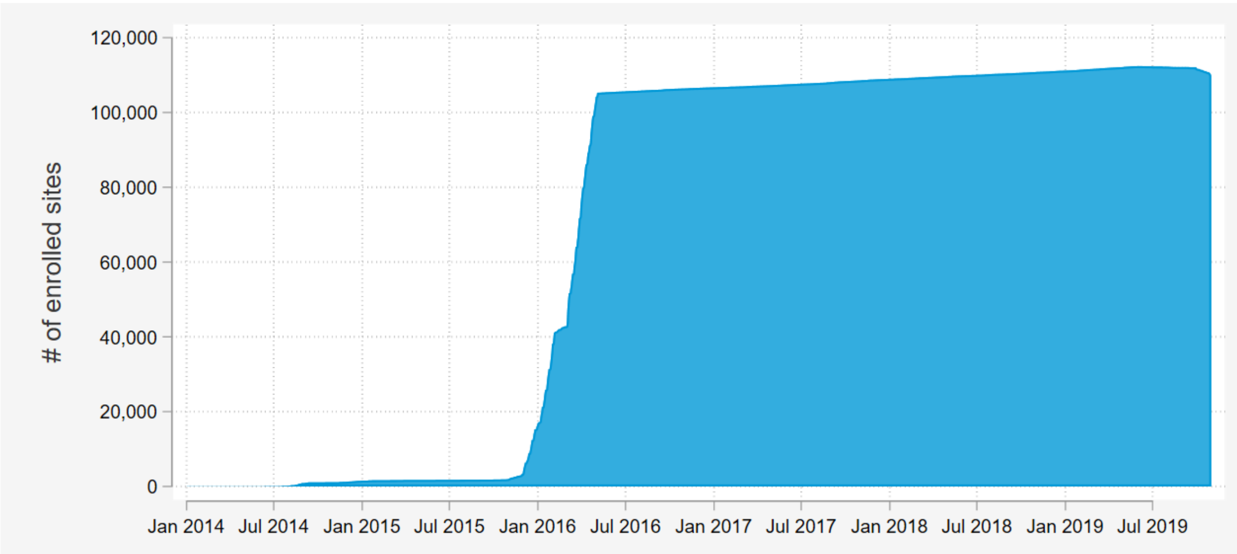
	CPP-TOU	TD Programs
Data sources / samples	▪ Hottest 20 weekdays and weekends over the past three summers with events (2016-2018), plus any additional event days for: ✓ 115k Small Commercial ✓ 5.5k CPP-TOU opt outs (to be used for match control group[4]) ✓ 124 Ag participants ✓ 2.5k Ag participants (to be used for match control group[5])	▪ Hottest 20 weekdays and weekends over the past three summers (2016-2018, plus 2019 for ACSDA), plus any additional event days, for event day impacts
Segment-ation	▪ Rate ✓ Small Commercial vs Ag ▪ Enrollment in event notification (Y/N) ▪ Climate zone (Coastal vs Inland) ▪ Dual enrollment (other DR programs) ▪ Net metering status (Y/N)	▪ Rate ✓ CPP-TD: PSW (Small) vs CPP-D (Med & Large) ✓ ACSDA: Small vs Med vs Large vs Quasi-residential ▪ Climate zone (Coastal vs Inland)
Estimation method: Ex-post	Not Applicable (no events)	CPP-TD: Not Applicable (no events) ACSDA: Panel regression with multiple matched control group for each customer.
Estimation method: Ex-ante	▪ Weather normalized customer regressions by segment for reference loads	▪ Weather normalized customer regressions by segment for reference loads ▪ Regression of historical event percent impacts versus weather for percent reductions ▪ CPP-TD: Used 2016-2018 impacts ▪ ACSDA: Used 2016-2019 impacts

[4] Excludes 2.3k sites for customers receiving notifications to ensure no treatment effects for the control pool
[5] Excludes 830 sites for customers receiving notifications to ensure no treatment effects for the control pool

3 CRITICAL PEAK PRICING EVENT DAY IMPACTS

SDG&E defaulted over 120,000 small customer sites[6] onto CPP-TOU rates between November 2015 and April 2016. Roughly 5% of these customers opted-out and were placed on TOU rates. Figure 3 shows this cumulative enrollment in CPP, net of the opt-outs.

Figure 3: Small Non-Residential Critical Peak Pricing Enrollment



The first event season for CPP was in 2016, but only one CPP event was called that year. It was called on SDG&E's peak day, Monday, September 27th. The PY 2016 evaluation for small customers found that the ex post load impacts for this lone CPP event were not statistically significant. The event was atypical. SDG&E had a low notification rate at the time – less than 25% of customers had elected to provide contact information to SDG&E –notifications were sent the Friday prior to the Monday event, and the event occurred near the end of the summer season.

In PY 2017, there were three consecutive CPP events, including one weekend event, and significant impacts were identified. In addition, roughly 45% of sites signed up for event notification but, because several customers had multiple sites (but only signed up some), approximately 60% of sites received event notification. In PY 2018, six CPP events were called in July and August. The rates of notification were similar. In PY 2019, there were no CPP events.

[6] Here and through this report a site is defined as a premise and service point combination. Note that this figure is slightly higher than the number of sites used for the PY 2018 ex post impact analysis which only included sites still on CPP-TOU rates in PY 2018.

3.1 PARTICIPANT AND EVENT CHARACTERISTICS

In previous program years, CPP event impacts were assessed by site (premise and service point combination). These historical ex post impacts are used for the PY 2019 ex ante estimation.

3.2 DATA SOURCES AND ANALYSIS METHOD

Table 5 summarizes the five data sources used to conduct the PY 2018 CPP analysis. The resulting impacts from that evaluation were used to develop ex ante projects for PY 2019 and are provided below for reference. The PY 2018 ex post analysis conducted in 2019 and reported in the PY 2018 evaluation report was done by site on hourly load data. Various data sources were used to classify sites into the study segments. While different segments were developed for the various analyses in this report (rate versus technology based, event and non-event), the characteristic definitions used to build segments were consistent across analyses.

Table 5: Critical Peak Pricing Evaluation Data Sources

Source	Comments
Hourly interval data	▪ Summer 2018 (June 1 through October 31) ▪ All analysis done by site (premise id-service point id pair)
Customer characteristics	▪ Treatment: All small non-residential (Commercial and Agricultural) CPP rates (114,923 sites) ▪ Control: TOU only rates (5.5k sites) ▪ Industry, zip codes, climate zone, NEM status used in matching model selection ▪ NEM status, climate zone, and DR program enrollment used for segmentation
SDG&E hourly system loads	▪ Summer 2018 (June 1 through October 31) ▪ Used to identify non-event high system load days
Ex post weather data by weather station	▪ Used to derive cooling degree days for impact evaluation panel model
Event notification	▪ List of notifications sent to each account for each event day ▪ Rolled up by customer to identify customers who had received notifications at any site (used for segmentation)

In the PY 2018 analysis propensity score matching was used to select a matched control for the roughly 115,000 TOU-CPP sites among a control candidate pool of roughly 9,300 TOU sites (e.g., those that opted out of TOU-CPP and are no longer receiving notifications). A difference-in-difference panel regression model with fixed effects was then used to assess impacts and standard errors for each event and each study segment.

3.3 EX POST LOAD IMPACTS

No CPP events were called in PY 2019 so there are no event impacts to assess. PY 2018 impacts were used to estimate ex ante impacts.

3.4 EX ANTE LOAD IMPACTS

A key objective of the 2019 evaluation is to quantify the relationship between demand reductions, temperature and hour of day. Ex ante impacts are estimated load reductions as a function of weather conditions, time of day, and forecasted changes in enrollment. By design, they reflect planning conditions defined by normal (1-in-2) and extreme (1-in-10) peak demand weather conditions. The historical load patterns and performance during actual events are used to estimate the reductions for a standardized set of weather conditions. Since no new events were call during PY 2019, historical impacts during events from 2016 through 2018 were used.

At a fundamental level, the process of estimating ex ante impacts included five main steps:

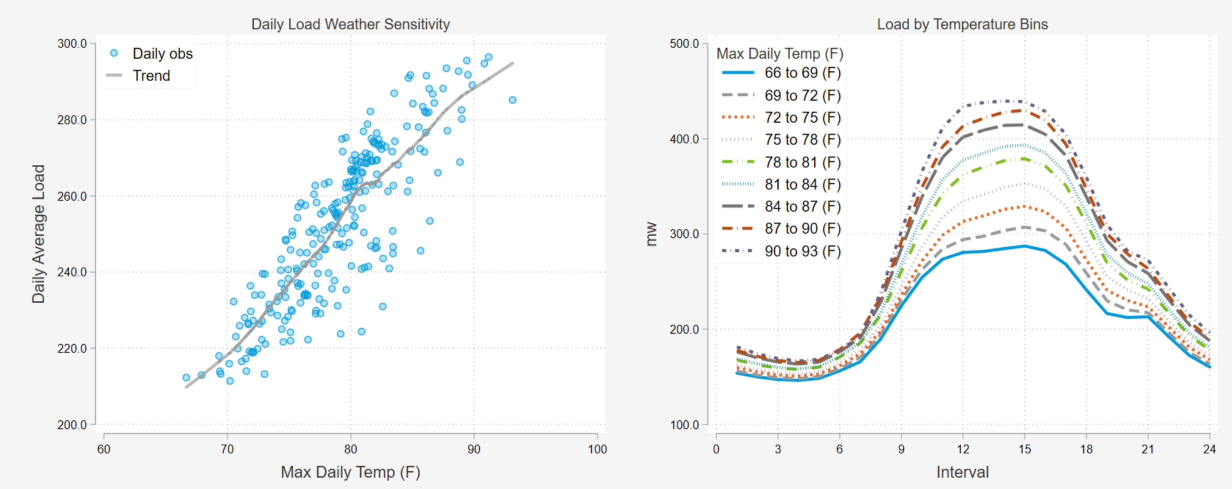
1. Estimate the relationship between customer loads (absent DR) and weather
2. Use the models to predict customers loads (absent DR) for 1-in-2 and 1-in-10 weather year conditions
3. Apply the average percent reductions, at an hourly level, from historical events. The average reduction was employed because experience with small business default CPP is limited and there is less of a history of program performance across events.
4. Estimate reductions for 1-in-2 and 1-in-10 weather year conditions
5. Incorporate the enrollment forecast

3.4.1 RELATIONSHIP OF CUSTOMER LOADS AND PERCENT REDUCTIONS TO WEATHER

Figure 4 summarizes the relationship between weather and CPP participant loads in 2016 through 2018. Only days when CPP resources were not dispatched are included. The panel to the left shows average hourly loads for current participants for different temperature bins, defined by the daily maximum temperature. The panel to the right shows the relationship between daily maximum temperatures and hourly loads. Overall, energy demand and discretionary load increases with hotter weather.

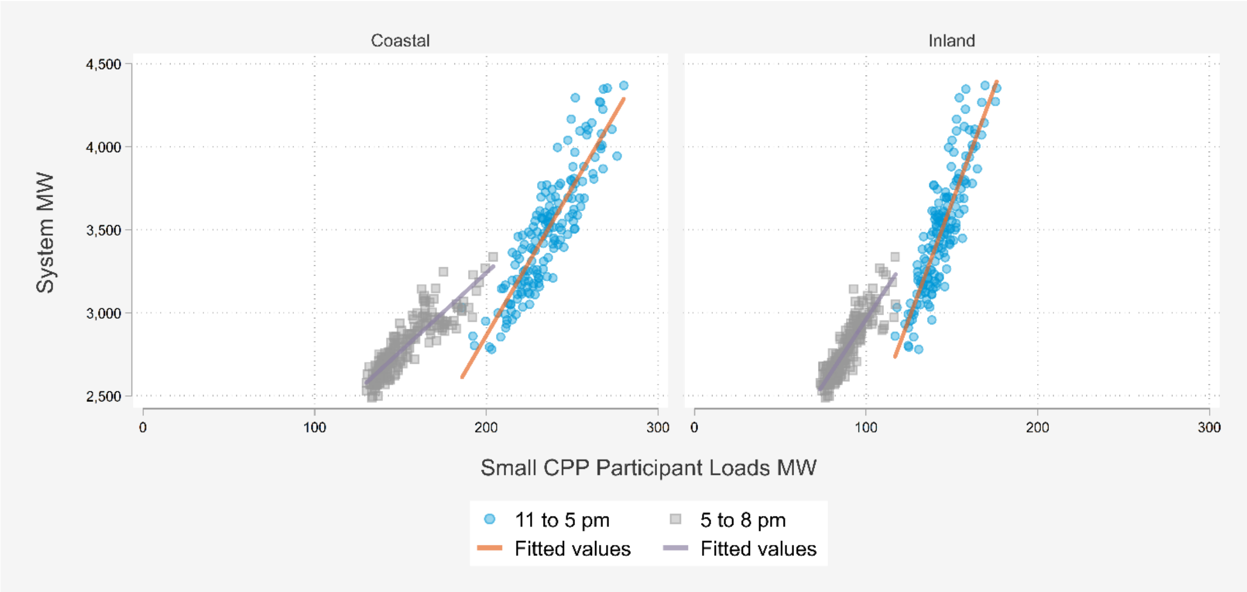
Figure 5 shows the relationship between aggregate small commercial CPP loads and SDG&E daily peak loads. Daily peaks that occurred before 5pm are shown in blue and those that occurred later are shown in grey. Daily peaks that occur later in the day (after 5pm) are smaller in magnitude and occur on days where maximum daily temperatures are about 5 to 10 degrees cooler than days with earlier peaks. Not surprisingly, small commercial customers use more power when it is extremely hot and contribute to peak demand, which drives the need for additional generation, transmission, and distribution infrastructure. Based on our analysis, we estimated that loads from small commercial CPP participants account for approximately 10% of SDG&E's peak load absent demand response. Customers in the Coastal climate zone comprise about 60% of these loads. Because small commercial loads are a major driver of SDG&E peaks, if managed, they can reduce the need to build additional infrastructure to accommodate additional peak load. Because more discretionary load is in use during peaking conditions, reductions from CPP participants can be larger precisely when resources are needed most.

Figure 4: Weather Sensitivity of Small Commercial CPP Loads



2016-2018 June to Sept loads, excluding weekends/holidays and events

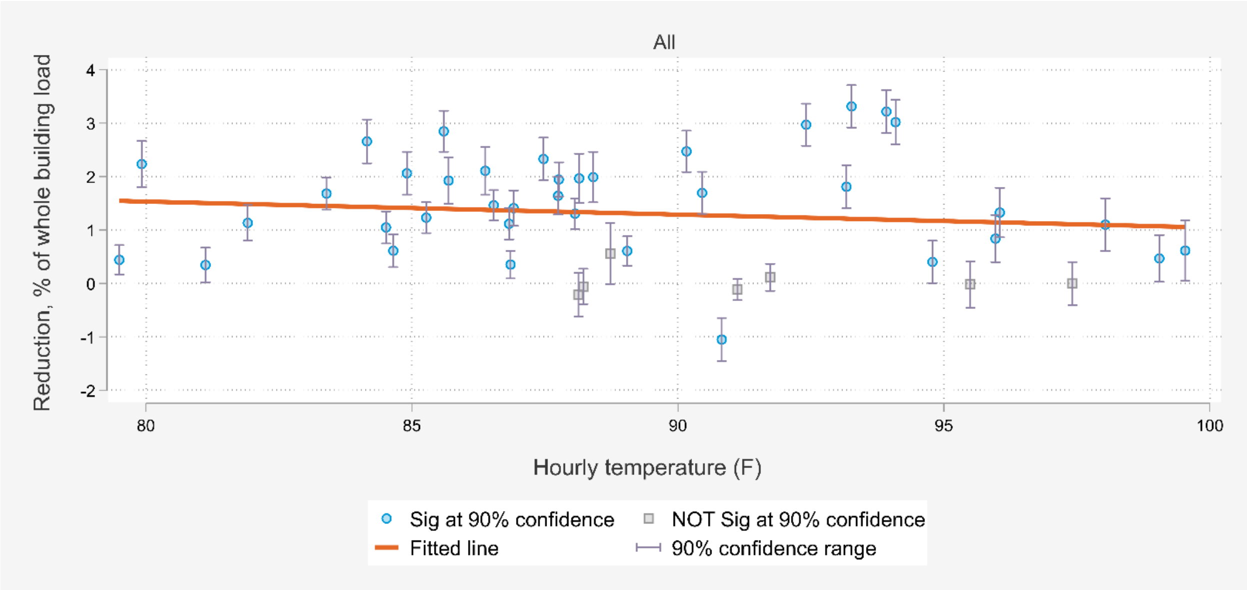
Figure 5: Small CPP Load versus System Daily Peaks



Because of the limited history of default CPP events, the main driver of differences in ex ante impacts are differences in loads. Since the implementation of default CPP, a total of ten events have been called. The first, on September 26, 2016 was unusual. The heat wave occurred near the end of summer, on a Monday, when the share of customers signed up for event notification was lower. Of the three 2017 events, one was on the weekend and has limited value in helping estimate weekday peak reduction capability. As a result, the weekday events called on August 31 and September 1, 2017 were used to estimate the average hourly percent change in demand. All six events called in 2018 were included in the ex ante model estimation. The percent change in energy use was estimated for each of the ex post segments defined in Table 4 and applied to 1-in-2 and 1-in-10 weather year customer loads.

Figure 6 shows hourly event percent reductions for these events as a function of hourly temperatures. Note that while most reductions are positive in magnitude, a handful are near zero (and not statistically significant) and few are negative, indicating an increase in load. The one event with significant negative reductions was July 6, 2018, an extreme heat wave day with unusually hot temperatures.

Figure 6: 2016-2018 Small CPP Hourly Reductions and Temperatures



3.4.2 Ex Ante Load Impacts

Table 6 summarizes the ex ante demand reduction capability by forecast year and planning condition. The tables reflect dispatchable demand reductions available from 4 pm to 9 pm on August monthly peaking conditions for 1-in-2 and 1-in-10 weather conditions. They align with the planning conditions used for resource adequacy attribution. To avoid double counting, the table only includes resources that are not dually enrolled in other DR programs, known as portfolio impacts.

Table 6: Small CPP Portfolio Impacts for August Monthly Peak Day (4-9 pm)[7]

Year	Sites	CAISO		SDG&E	
		1-in-2	1-in-10	1-in-2	1-in-10
2019	111,149	1.97	1.96	1.97	1.97
2020	107,603	1.91	1.90	1.91	1.90
2021	104,170	1.85	1.84	1.85	1.84
2022	100,846	1.79	1.78	1.79	1.78
2023	97,629	1.73	1.72	1.73	1.73
2024	94,514	1.67	1.67	1.68	1.67
2025	91,498	1.62	1.61	1.63	1.62
2026	88,579	1.57	1.56	1.57	1.57
2027	85,753	1.52	1.51	1.52	1.52

[7] Small commercial impacts only. Excludes 124 Agricultural sites for which aggregate loads and impacts are negligible. Results for Agricultural sites are available in the accompanying Ex ante table generator.

Year	Sites	CAISO		SDG&E	
		1-in-2	1-in-10	1-in-2	1-in-10
2028	83,017	1.47	1.46	1.47	1.47
2029	80,369	1.42	1.42	1.43	1.42
2029	77,806	1.56	1.55	1.50	1.66

The enrollment forecast was developed by SDG&E and shows a declining number of customers enrolled in CPP. Over time, customers are expected to sort themselves between TOU-CPP and TOU rates. For ex ante impacts, reduction in enrollment forecasts are assumed to have a proportional effect of the magnitude of demand reduction resources. This assumption is conservative. In past implementations, less price responsive customers opted out of default CPP rates, leading to lower enrollment rates, but a limited effect on reduction capability.

3.4.3 COMPARISON OF EX POST AND EX ANTE LOAD IMPACTS

Table 7 compares the demand reductions from 2018 events to the reduction expected for the 1-in-2 weather conditions used for planning. Results are shown for both the 4 to 9 pm resource adequacy window. In PY 2018, the most recent year where CPP events were called, small CPP customers delivered 2.72 MW during the dispatch period of 2 to 6 pm. The 4 to 9 pm ex post reductions are much lower, 0.69 MW, because CPP events can only be called from 2 to 6 pm. When similar hours are compared, ex ante resource estimates are somewhat higher than the ex post impacts. With such small impacts (on the order of 1%) such variability is to be expected.

Table 7: Small CPP Comparison of PY 2018 Ex Post and PY 2019 Ex Ante Load Impacts

Result Type	Day Type and Period	Sites	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)
Ex Post Avg. Weekday (PY2018 Results)	Event Period (2pm to 6pm)	111,149	395.33	2.72	0.7%	90.4
	Resource Adequacy Period (4 to 9pm)	111,149	315.03	0.69	0.2%	90.4
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	111,149	305.49	1.97	0.6%	88.6
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	111,149	307.89	1.97	0.6%	88.6

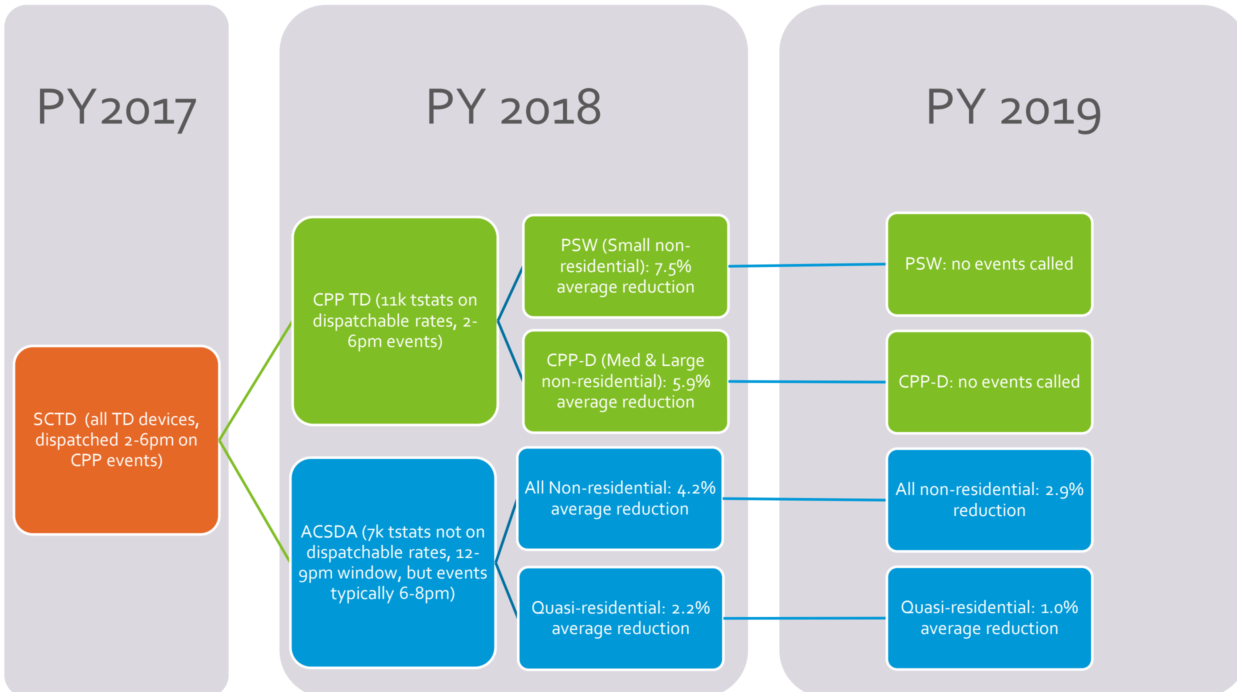
*Table shows portfolio impacts. To avoid double counting, it excluded commercial thermostats and customers dually enrolled in other DR programs. Also excludes 124 Agricultural sites for which aggregate loads and impacts are negligible.

4 COMMERCIAL THERMOSTAT EVENT DAY IMPACTS

Customers undergoing the transition to time varying rates were eligible for free Ecobee thermostats to help automated price response during critical peak periods. The thermostats can also help reduce electricity consumption when a business is unoccupied. The program was known as the Small Commercial Technology Deployment (SCTD) and has been in operation since 2014. However, prior to 2017, customers were not required to be on a CPP rate and, as a result, SCTD also included participants who are enrolled in TOU only rates with no dispatchable component. Historically, all thermostats were dispatched from 2-6 pm and Technology Deployment events coincided with CPP events, of which there were one in 2016 and three in 2017.

In 2018, the program changed from a free thermostat to a rebate model and was broadened to include additional thermostat models. Figure 7 summarizes four the specific program designations for the PY 2019 evaluation. There are two programs (and accompanying rates) for customers on CPP-TOU rates: Peak Shift at Work (PSW) for Small non-residential customers and CPP-D for Medium and Large non-residential customers. Devices enrolled in these programs are dispatched during CPP events, of which there were none in PY 2019. For customers who are not on dispatchable rates, there are also two programs AC Saver Day Ahead (ACSDA) for non-residential customers and ACSDA for quasi-residential customers (who are on residential rates). ACSDA events are typically called from 6 to 8 pm. ACSDA thermostats can be dispatched at any time between 12 pm to 9 pm (on-peak hours) for a maximum of 4 consecutive hours and most events in 2019 were called from 6-8pm. For all four programs, devices are curtailed by raising the thermostat temperature set point 4 degrees during the event window.

Figure 7: Summary of TD Program Taxonomy



There are over 18,000 devices installed at over 3,000 non-residential sites. Roughly 11,000 devices are installed at sites on dispatchable rates (small commercial on PSW and medium and large on CPP-D) and the remaining 7,000 are installed at non-residential and quasi-residential sites on non-dispatchable rates enrolled in AC Saver Day Ahead (ACSDA). As noted above, no events were called for sites on dispatchable rates (CPP-TD). Reductions for ACSDA sites, while statistically significant on average and consistently positive across events, were somewhat smaller than in PY 2018 (3% versus about 4%). These relatively low impact magnitudes remain can mostly be explained by the late ACSDA dispatch window (6 to 8pm for most events) and cooler weather (over half of ACSDA event were called on days with max temperatures below 86F).

A key finding was that only about 40% of installed devices were connected during the PY 2019 event season, down from over 50% connected during PY 2018. Because only connected devices can receive signals and curtail AC load this lack of connectivity has direct implication for load impacts delivered by the Technology Deployment programs. The decline in connectivity appears to be substantial and continues to be relatively steady over time, ranging from 13% to 23% per year for most programs[8]. Because of the decline impacts were derived at a per connected thermostat basis so they could be applied to enrollment forecasts reflecting numbers of connected devices in addition to enrolled sites.

[8] With the exception of ACSDA quasi-residential sites where hundreds of sites managed by a single customer were disconnected around the same time in late 2017.

Future efforts to reconnect disconnected devices, particularly among programs or customer segments delivering greater reductions, could substantially increase future load reduction potential for the Technology Deployment programs.

4.1 TECHNOLOGY AND EVENT CHARACTERISTICS

The thermostats used as the enabling device receive a signal from SDG&E to curtail usage during events. For all PY19 events, thermostats were controlled by raising the setpoint temperature by 4 degrees. This approach is intended to reduce energy usage by air conditioning units. However, to receive the curtailment signals, the devices must be connected to the internet and registered in the SDG&E dispatch portal. This is initially set up during the device installation process, but connectivity can be affected by internet reliability. Once connected, the device can receive and execute curtailment signals, and it can also communicate event notifications to users before the beginning of an event. Participating, connected devices were sent event notifications 24 hours prior to an event.

Figure 8 shows cumulative thermostat installations over time (in blue) across all four Technology Deployment programs—most devices were installed by the end of 2016 and new installations have leveled off since then. It also shows the cumulative count of connected thermostats and highlights the decline in connectivity rates over time. Installation and connectivity rates are lowest among the ACSDA quasi-residential program. The other three programs maintain connectivity rates of about 45%: about 48% for non-res ACSDA and 43% for CPP-TD programs.

Figure 8: Commercial Thermostat Cumulative Installations and Connectivity

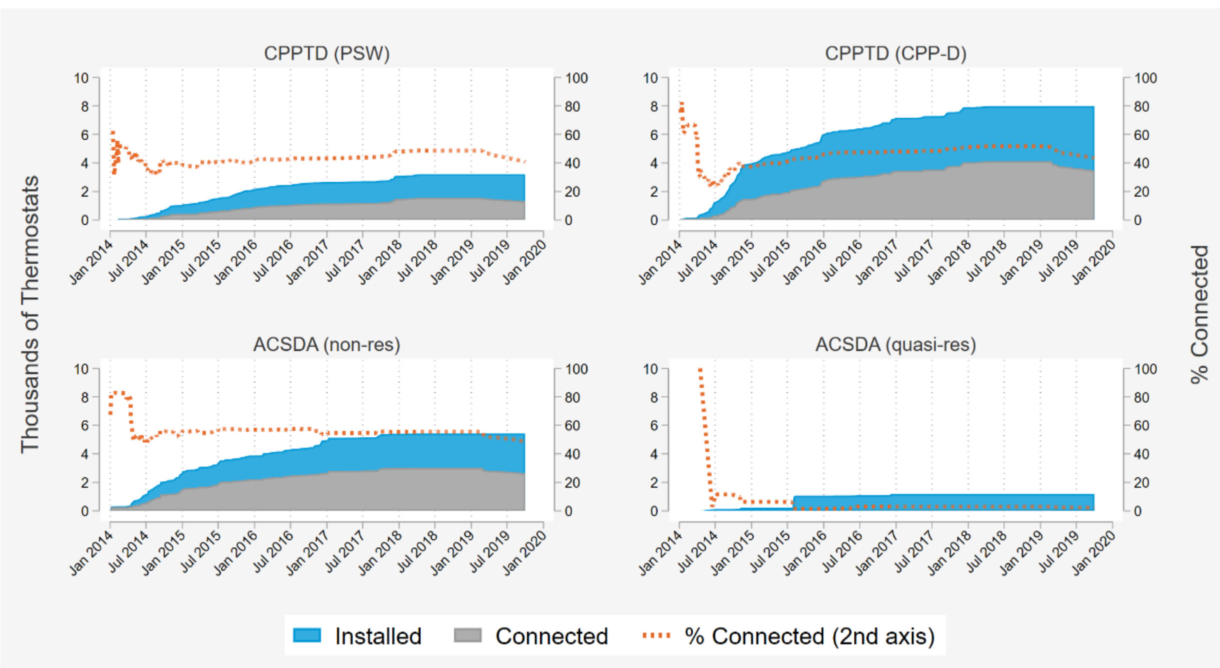


Figure 9 show the proportion of devices still connected N years after installation for each program. Aside from ACSDA Quasi-residential customers, for which a majority of devices were disconnected by a single multi-family building on the same date, these survival curves indicate a decay rate consistent with an unintentional loss of connectivity over time. Given that load reductions are delivered by connected devices, this drop in connectivity combined with the leveling of installations has implications for load reductions that can be expected for TD programs. Unless efforts are made to reconnect devices, future program reductions are expected to decline along with device connectivity.

Figure 9: Thermostat Connectivity Survival Curves for CPP Programs

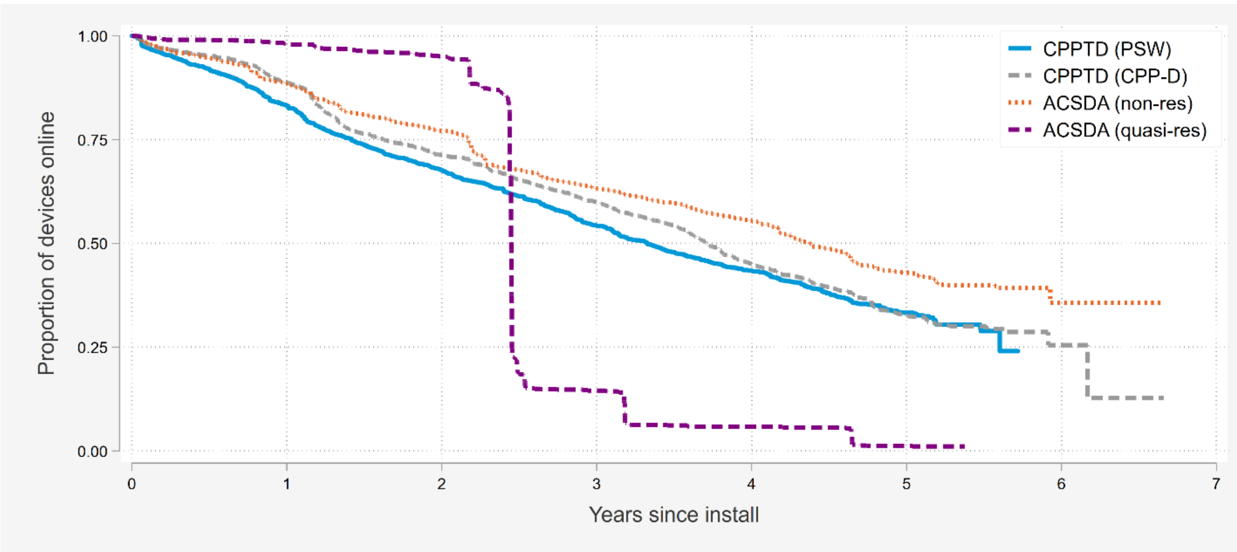


Table 8: Thermostat Connection Decay Rates for TD Programs

Program	Failure Rate	95% Confidence Lower Bound	95% Confidence Upper Bound
CPPTD (PSW)	20.89%	19.97%	21.86%
CPPTD (CPP-D)	19.28%	18.70%	19.89%
ACSDA (non-res)	15.77%	15.22%	16.34%
ACSDA (quasi-res)	38.43%	36.27%	40.73%

Table 9 shows program counts for enrolled sites, installed thermostats, and connected thermostats during the average PY 2019 event. Importantly, a substantial number of devices were no longer connected to the SDG&E dispatch portal during PY 2019 and therefore could not be curtailed during events[9]. There are multiple reasons why a thermostat can become disconnected: a change in routers, a change in Wi-Fi passwords, deliberate disconnection (opt-outs), replacement of the thermostat, etc. When router or Wi-Fi passwords change, a thermostat may not be reconnected by the customers. Understanding the reason why thermostats become disconnected and how to effectively encourage customers to reconnect is critical to the long-term success of the program.

Commercial thermostat event impacts were assessed by site (premise and service point combination). After initial analysis confirmed that no perceptible, meaningful, or significant impacts were observed for sites with zero connected thermostats in 2019, the analysis was narrowed to focus on sites with at least one thermostat connected at the time of the first event (April 24, 2019)[10]. Sites were grouped together into segments to assess potential differences in impacts for various groups. The segmentation, summarized in Table 9, was developed based on rate size and on rate characteristics which may influence impacts. The analysis was performed at the segment level so these granular impacts could therefore be summed, yielding aggregate impacts in addition to the segment specific impacts.

The segmentation criteria were defined as follows:

- **Rate:** was the site on a rate with a CPP component during the study period?
- **Rate size**: what size (demand level for rate[11]) was the site classified as throughout the study period?
- **Climate zone:** in which SDG&E climate zone was the site located?

Table 9: Commercial Thermostat Programs and Populations

Program Rate	Size	Climate zone	Total sites	Total Connected sites	Connected sites in event analysis	Total installed devices	Total connected devices
ACSDA (non-res)	Large	Coastal	26	18	18	858	407
		Inland	40	34	33	1,958	1,050

[9] Sites with zero connected devices were analyzed to confirm that no event impacts were observed.
[10] Given that disconnected sites delivered zero impacts, including them in the analysis would needlessly add statistical noise inherent in load patterns. Impacts across all sites were calculated by adding the load observed for disconnected sites to the reference loads estimated for connected sites.

[11] Small sites are on AS rates (such as ATOU and ASTODPSW) and have maximum demand below 20 kW—classification was assigned by rate. Medium and large sites are on AL rates or PA CP2 rates (such as ALTOU or PATODCP2). Medium sites were distinguished from Large sites by applying a maximum demand cutoff of 200 kW.

Program Rate	Size	Climate zone	Total sites	Total Connected sites	Connected sites in event analysis	Total installed devices	Total connected devices
	Medium	Coastal	88	63	62	1,216	669
		Inland	102	65	64	1,609	652
	Small	Coastal	54	36	35	207	87
		Inland	45	24	23	156	49
ACSDA (quasi-res)	Quasi-res	Coastal	899	8	8	957	12
		Inland	198	18	18	216	14
TOTAL			**1,452**	**266**	**261**	**7,177**	**2,939**

Table 9 also summarizes the total number of sites in each segment and the final number of sites used for the ex post event analysis once data cleaning was completed[12]. As one might expect, smaller sites are more numerous but larger sites have more devices per site. Of particular note is the quasi-residential group, which comprises over 1,000 sites with an average of one device per site but for which the vast majority of sites were disconnected in 2019. Analysis from PY 2017 demonstrated that loads for quasi-residential sites are highly correlated given that hundreds of sites are typically managed by a single customer and impacts were analyzed using a methodology tailored to this type of data. However, given the small number of connected devices and sites remaining in PY 2019, quasi-residential sites were analyzed using the same synthetic matched control group methodology as all other sites.

Table 10 shows the nineteen PY 2019 ACSDA event days. Historically, ACSDA events have been called more frequently than CPP events, are called during later dispatch windows (6 to 8pm for most events compared to 2 to 6pm for CPP events) and are called during cooler weather. The ACSDA season started earlier in PY2019 than in previous years, with the first event occurring in April, and continued to be dispatched until late October. It also included one weekend event on August 4.

[12] The cleaning algorithm ensured that complete data was available for the study period. Loads and impacts were scaled to address the five sites not in the analysis.

Table 10: Commercial Thermostat ACSDA Events in 2019

Event day	Day of week	Event start	Event end	Max daily temp (F)	SDG&E system load (MW)
4/24/2019	Wednesday	7:00 PM	9:00 PM	76.4	2,599
7/22/2019	Monday	6:00 PM	9:00 PM	83.9	3,130
7/23/2019	Tuesday	6:00 PM	8:00 PM	88.1	3,500
7/24/2019	Wednesday	6:00 PM	8:00 PM	90.7	3,654
7/29/2019	Monday	6:00 PM	8:00 PM	84.2	3,146
8/4/2019	Sunday	6:00 PM	8:00 PM	85.2	3,040
8/5/2019	Monday	6:00 PM	8:00 PM	85.3	3,310
8/6/2019	Tuesday	6:00 PM	8:00 PM	84.0	3,205
8/14/2019	Wednesday	6:00 PM	8:00 PM	86.0	3,320
8/15/2019	Thursday	6:00 PM	8:00 PM	85.9	3,209
8/26/2019	Monday	6:00 PM	8:00 PM	89.3	3,666
8/27/2019	Tuesday	6:00 PM	8:00 PM	84.9	3,438
9/5/2019	Thursday	5:00 PM	8:00 PM	89.7	4,034
9/6/2019	Friday	6:00 PM	8:00 PM	89.9	3,958
9/23/2019	Monday	1:00 PM	4:00 PM	80.9	3,032
10/7/2019	Monday	6:00 PM	8:00 PM	85.3	2,930
10/22/2019	Tuesday	5:00 PM	8:00 PM	92.9	3,260
10/23/2019	Wednesday	6:00 PM	8:00 PM	88.4	3,133
10/24/2019	Thursday	5:00 PM	7:00 PM	92.8	3,424

4.2 DATA SOURCES AND ANALYSIS METHOD

Table 11 summarizes the five data sources used to conduct the commercial thermostat event impact analysis. The analysis was done by site on hourly load data. Various data sources were used to classify sites into the study segments. While different segments were developed for the various analyses in this report (rate versus technology based, event and non-event), the characteristic definitions used to build segments were consistent across analyses.

Table 11: Commercial Thermostat Event Impact Evaluation Data Sources

Source	Comments
Hourly interval data	▪ Summer 2019 ▪ All analysis done by site (premise id-service point id pair)
Customer characteristics	▪ Treatment: All non-residential (Commercial and Agricultural) commercial thermostat participants, including quasi-residential sites ▪ Control: All non-residential sites not on CPP or other DR programs ▪ Industry, zip codes, climate zones used in matching model selection
Thermostat installation data	▪ Installation and last connected dates
SDG&E hourly system loads	▪ Summer 2019 ▪ Used to identify non-event high system load days
Ex post weather data by weather station	▪ Used to derive cooling degree hours for impact evaluation panel model

The primary analysis method was a panel regression with a multiple matched control groups. The distance matching approach used selected five matched control sites for each of the roughly 1,450 non-residential ACSDA sites among a control candidate pool of roughly 17,000 TOU sites who were not enrolled in CPP or other DR programs which might influence energy use. The panel regression model was then used to assess impacts and standard errors for each event and each study segment.

To identify which model best predicted customer loads absent demand reductions, an out of sample approach was still used to select the model specification. The model selection relied on testing how well each model estimated loads for hot non-event days out-of-sample. Because there was, in fact, no event, it was possible to assess how close model estimates were to the correct answer and the most accurate model. A total of 60 models were tested to select the number of proxy days, number of matched controls, and structure of same day adjustments to use. The regression model structure is detailed in the Appendix.

4.3 EX POST LOAD IMPACTS

4.3.1 AC SAVER DAY AHEAD: NON-RESIDENTIAL WITH TECHNOLOGY

The AC Saver program called 19 events during PY 2019. The ACSDA events were typically called from 6 to 8 pm, though six events were called during slightly different windows and another event was called on a weekend. The remaining events are used to create the Average Event impacts. In addition to being called later in the day when commercial AC loads are lower, several ACSDA events were also called later in the season on cooler days. Load reductions were significant for most individual events. The average event window was also significant with an average aggregate reduction of 0.51 MW.

Table 12 summarizes the load reductions for all Non-Residential ACSDA sites for the 19 events and 6 pm to 8 pm reductions for the average event. The full event hours for the seven non-standard event days are provided at the bottom of Table 12. None of these are included in the calculations for the average event. The average aggregate load reduction for all event days from 6 to 8 pm was 0.51 MW across all 355 enrolled sites and the average reduction per site was 2.12 kW. Though 6,004 devices were installed at enrolled sites, only 2,913 devices on average were connected during the PY 2019 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.18 kW. Impacts tended to be larger for events where the average event temperature was higher.

Reductions were marginally significant and very small in magnitude on average, with 14 events producing reductions significant at the 90% level. Aggregate reductions for significant events range from 0.39 MW (July 24) to 1.00 MW (August 15). These dates, respectively, also exhibited the highest and lowest average site reductions and average connected thermostat reductions of the significant events.

Table 12: ACSDA Non-Residential Program Event Reductions

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
7/23/2019	6 to 8 pm	80.1	355	6,004	2,980	0.49	2.02	0.16	2.30	Yes
7/24/2019	6 to 8 pm	78.1	355	6,004	2,977	0.39	1.60	0.13	2.81	Yes
7/29/2019	6 to 8 pm	73.6	355	6,004	2,973	0.45	1.87	0.15	1.30	No
8/5/2019	6 to 8 pm	74.3	355	6,004	2,964	0.50	2.06	0.17	1.98	Yes
8/6/2019	6 to 8 pm	71.3	355	6,004	2,962	0.85	3.51	0.29	3.56	Yes
8/14/2019	6 to 8 pm	74.7	355	6,004	2,943	0.50	2.08	0.17	2.52	Yes
8/15/2019	6 to 8 pm	72.6	355	6,004	2,943	1.00	4.16	0.34	4.18	Yes
8/26/2019	6 to 8 pm	76.6	355	6,004	2,932	0.13	0.56	0.05	0.73	No
8/27/2019	6 to 8 pm	73.4	355	6,004	2,932	0.46	1.92	0.16	2.02	Yes
9/6/2019	6 to 8 pm	78.6	355	6,004	2,919	0.80	3.30	0.27	5.08	Yes
10/7/2019	6 to 8 pm	69.9	355	6,004	2,789	0.22	0.91	0.08	1.53	No
10/23/2019	6 to 8 pm	70.0	355	6,004	2,643	0.34	1.42	0.13	0.94	No
Avg Event	**6 to 8 pm**	**74.4**	**355**	**6,004**	**2,913**	**0.51**	**2.12**	**0.18**	**7.05**	**Yes**
4/24/2019	7 to 9 pm	62.6	355	6,004	3,096	0.11	0.45	0.03	0.65	No
7/22/2019	6 to 9 pm	73.8	355	6,004	2,980	0.66	2.75	0.22	4.04	Yes
8/4/2019	6 to 8 pm	73.2	355	6,004	2,964	0.55	2.28	0.19	5.60	Yes
9/5/2019	5 to 8 pm	80.8	355	6,004	2,920	0.65	2.67	0.22	4.12	Yes
9/23/2019	1 to 4 pm	79.9	355	6,004	2,879	0.86	3.56	0.30	3.53	Yes
10/22/2019	5 to 8 pm	77.3	355	6,004	2,648	0.55	2.28	0.21	3.33	Yes
10/24/2019	5 to 7 pm	83.9	355	6,004	2,638	0.74	3.05	0.28	3.86	Yes

Reductions were also analyzed within climate zone for Small, Medium, and Large customers in the ACSDA program. Table 13 details the reference loads and load reductions overall and by size-climate zone segment for the average 6 pm to 8 pm event window. In addition to aggregate reductions, average reductions per connected thermostat are also shown. Note that the reference load for aggregate impacts includes the whole building load across all enrolled sites as recorded at the meter; the reference load for the average connected thermostat is the cooling load per connected thermostat, estimated by isolating the weather sensitive portion of whole building load. In aggregate, 2.9% of whole building load was curtailed during the average event, while 27% of cooling load was curtailed per connected device.

In aggregate, about 34% of connected devices were in the coastal zone and these devices delivered 0.26 MW of the 0.71 MW—about one third—of reductions for the ACSDA Non-Residential program. Large customers exhibited the largest reference loads in aggregate and per connected thermostat. Significant load reductions were not found for small customers in either climate zone.

Table 13: ACSDA Non-Residential Program Average Event Reductions by Segment

Size	Climate zone	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW)			Average connected tstat (kW)			t-stat
							Ref load (whole bldg)	Reduc-tion	% Reduc-tion	Ref load (cooling)	Reduc-tion	% Reduc-tion	
Large	Coastal	6 to 8 pm	72.8	26	858	407	4.30	0.01	0.2%	1.00	0.02	2%	0.36
	Inland	6 to 8 pm	75.9	40	1,958	1,050	8.04	0.21	2.6%	1.01	0.20	20%	2.93
Medium	Coastal	6 to 8 pm	72.7	88	1,216	669	2.53	0.15	5.8%	0.53	0.22	41%	10.50
	Inland	6 to 8 pm	75.8	102	1,609	652	2.22	0.13	5.8%	0.32	0.20	61%	8.66
Small	Coastal	6 to 8 pm	73.0	54	207	87	0.20	0.01	3.9%	0.31	0.09	29%	4.11
	Inland	6 to 8 pm	76.5	45	156	49	0.13	0.01	6.7%	0.14	0.18	129%	5.48
All	**All**	**6 to 8 pm**	**74.4**	**355**	**6,004**	**2,913**	**17.42**	**0.51**	**2.9%**	**0.65**	**0.18**	**27%**	**7.05**

The average event day load shape is summarized in greater detail in Figure 10. Note that the figure, extracted from the Ex Post Load Impact Table, is for the ACSDA non-residential participant population for the average event day. The average event day reflects days where event hours covered the 6 to 8 pm window, including days such as September 9 where the event window began earlier (5pm). The left panel shows the aggregate hourly MW loads (actual and counterfactual) for these sites. The right panel shows impacts per connected thermostat as a function of cooling load. Note that the cooling loads (kW per connected device, in the right panel) were estimated by isolating weather sensitive load from whole building load then divided by devices per site to yield cooling load per site. As expected, cooling load are more concentrated during the day when cooling loads tend to be a higher. The tables accompanying each figure show aggregate impacts for the 6 pm to 8 pm event window. Load reductions, though statistically significant, are smaller on a percentage basis (2.9%) than in PY 2018 (4.2%). Though aggregate load reductions are 2.9%, reductions are 27% of cooling load per connected thermostat. However, this 27% reduction translates to 0.18 kW per connected thermostat, which is equivalent to the connected thermostat reduction of PY 2018.

Figure 10: ACSDA Non-Residential Summary for Average Event

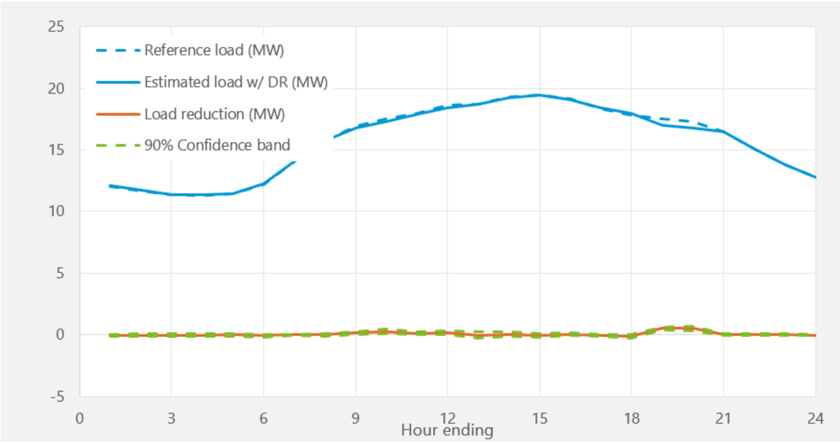
Update menus

Table 1: Menu options

Program	ACSDA (non-res)
Type of result	Aggregate
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	355
Total installed thermostats	6,004
Total connected thermostats	2,913
Percent of thermostats connected	49%
Avg load reduction 6PM-8PM	0.51
% Load reduction 6PM-8PM	2.9%



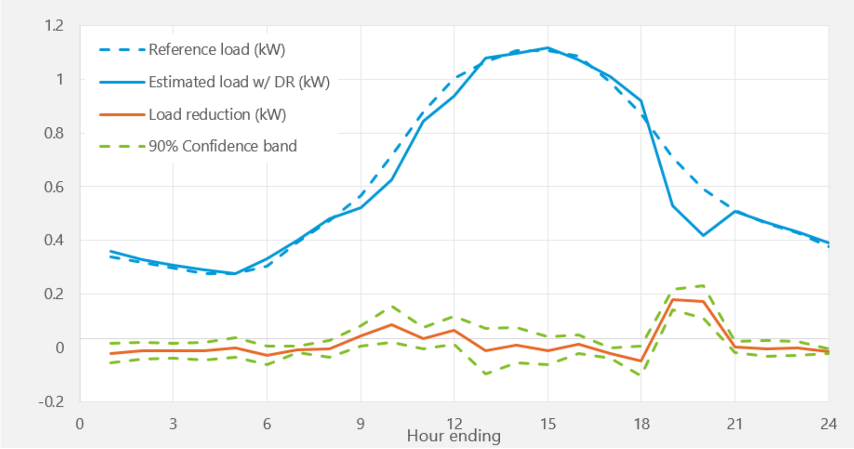
Update menus

Table 1: Menu options

Program	ACSDA (non-res)
Type of result	Average Connected Thermostat (Cooling load)
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	355
Total installed thermostats	6,004
Total connected thermostats	2,913
Percent of thermostats connected	49%
Avg load reduction 6PM-8PM	0.18
% Load reduction 6PM-8PM	27.0%



4.3.2 AC Saver Day Ahead: Quasi-Residential with Technology

Nineteen events were called for the AC Saver Day Ahead program during PY 2019. Like with enrolled non-residential sites, reductions were found to be statistically significant for quasi-residential enrolled sites. However, the number of connected sites and the loads per site are so small that aggregate load reductions were just 0.01 MW. As noted in the non-residential ACSDA section events were called later in the day and on cool days late in the season when cooling loads are already relatively low, likely contributing to the lack of reductions. In addition, only 27 thermostats were connected during PY 2019, making it difficult to detect any reductions. Greater impacts may be achieved by calling events earlier in the day or on hotter days and by reconnecting disconnected devices.

In addition, clusters of dozens or even hundreds of quasi-res sites are often managed by a single customer, reflecting the fact that quasi-residential customers are often property management companies. Based on observation, loads tend to be relatively correlated across sites managed by the same customer which further presents a challenge for detecting load reductions. However, most of the disconnected devices were managed by a single customer and were disconnected on or around the same date in 2017.

Table 14 summarizes the load reductions for all ACSDA Quasi-Residential sites for each of the 19 events and 6 pm to 8 pm reductions for the average event. As described in the non-residential ACSDA section, six events occurred during a different window than the other events and a seventh event occurred on a weekend (August 4). These seven events are presented in full below the average event details. Only weekday events called during the standard 6 pm to 8 pm window are included in the average event results. The average aggregate load reduction was 0.01 MW across all 1,173 enrolled sites and the average reduction per site was 0.52 kW and this was significant at the 90% confidence level (t-value = 10.86). Of 1,173 devices installed at enrolled sites, only 26 devices on average were connected during the PY 2019 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.52 kW.

Most events were statistically significant, with only August 5th falling short of the 90% significance level. Reductions were very small in magnitude on average, due to the limited number of connected devices.

Table 14: ACSDA Quasi-Residential Program Event Reductions

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
7/23/2019	6 to 8 pm	82.2	1,097	1,173	26	0.02	0.71	0.70	4.63	Yes
7/24/2019	6 to 8 pm	78.6	1,097	1,173	26	0.02	0.74	0.73	4.56	Yes
7/29/2019	6 to 8 pm	74.8	1,097	1,173	26	0.02	0.74	0.73	3.01	Yes
8/5/2019	6 to 8 pm	77.0	1,097	1,173	26	0.00	0.19	0.19	1.24	No
8/6/2019	6 to 8 pm	72.5	1,097	1,173	26	0.02	0.62	0.61	3.68	Yes
8/14/2019	6 to 8 pm	76.7	1,096	1,172	26	0.01	0.31	0.30	2.17	Yes
8/15/2019	6 to 8 pm	75.8	1,097	1,173	26	0.01	0.46	0.45	2.03	Yes
8/26/2019	6 to 8 pm	76.5	1,097	1,173	26	0.01	0.45	0.44	2.17	Yes
8/27/2019	6 to 8 pm	73.6	1,097	1,173	26	0.02	0.60	0.59	3.50	Yes
9/6/2019	6 to 8 pm	77.5	1,097	1,173	26	0.01	0.54	0.53	2.76	Yes
10/7/2019	6 to 8 pm	67.2	1,097	1,173	25	0.01	0.41	0.42	3.20	Yes
10/23/2019	6 to 8 pm	67.9	1,097	1,173	24	0.01	0.51	0.55	6.51	Yes
Avg Event	**6 to 8 pm**	**75.0**	**1,097**	**1,173**	**26**	**0.01**	**0.52**	**0.52**	**10.86**	**Yes**
4/24/2019	7 to 9 pm	61.9	1,097	1,173	27	0.01	0.28	0.27	2.69	Yes
7/22/2019	6 to 9 pm	76.9	1,097	1,173	26	0.01	0.53	0.53	5.64	Yes
8/4/2019	6 to 8 pm	75.1	1,097	1,173	26	0.01	0.55	0.54	3.05	Yes
9/5/2019	5 to 8 pm	81.0	1,097	1,173	26	0.01	0.50	0.50	3.98	Yes
9/23/2019	1 to 4 pm	83.3	1,093	1,169	25	0.00	0.17	0.17	1.92	Yes
10/22/2019	5 to 8 pm	74.3	1,097	1,173	24	0.01	0.53	0.56	4.96	Yes
10/24/2019	5 to 7 pm	81.4	1,097	1,173	24	0.02	0.78	0.84	4.07	Yes

Quasi-Residential reductions were also analyzed by climate zone segment. Table 15 details the reference loads and load reductions overall and by segment for the average 6 pm to 8 pm event window. In addition to aggregate reductions, average reductions per connected thermostat are also shown. Note that the reference load for aggregate impacts includes the whole building load across all enrolled sites as recorded at the meter; the reference load for the average connected thermostat is the cooling load per connected thermostat, estimated by isolating the weather sensitive portion of whole building load. In aggregate, 1% of whole building was curtailed during the average event, while 39% of cooling load was curtailed per connected device. While devices are split approximately evenly between the two zones, enrolled sites and reductions vary greatly. The coastal region has 12 connected thermostats, but exhibits 1.3% aggregate reduction and roughly 100%[13] reduction in cooling load for the average connected device. There are fewer enrolled sites in the inland climate zone, but slightly more connected thermostats in this region with 14 connected devices. Estimated savings were 0.2% of

[13] Cooling reductions greater than 100% reflect error in cooling load estimates

whole building load and 3% of cooling load. Due to the small sample size, load reduction results for ACSDA quasi-residential sites should be viewed with caution.

Table 15: ACSDA Quasi-Residential Program Average Event Reductions by Segment

Size	Climate zone	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW)			Average connected tstat (kW)			t-stat
							Ref load (whole bldg)	Reduc-tion	% Reduc-tion	Ref load (cooling)	Reduc-tion	% Reduc-tion	
Quasi-res	Coastal	6 to 8 pm	72.9	899	957	12	0.99	0.01	1.3%	1.04	1.06	103%	12.80
Quasi-res	Inland	6 to 8 pm	76.0	198	216	14	0.35	0.00	0.2%	1.61	0.05	3%	1.04
All	**All**	**6 to 8 pm**	**75.0**	**1,097**	**1,173**	**26**	**1.33**	**0.01**	**1.0%**	**1.32**	**0.52**	**39%**	**10.86**

The average event day load shape is summarized in greater detail in Figure 11. Note that the figure, extracted from the Ex Post Load Impact Table, is for the ACSDA quasi-residential participant population for the average event day. The average event day reflects weekday events where event hours matched the 6 to 8 pm window. The left panel shows the aggregate hourly loads (actual and counterfactual) for these sites. The right panel shows impacts per thermostat as a function of cooling load. The tables accompanying each figure show impacts for the 6 pm to 8 pm event window. Aggregate load reductions, though statistically significant, are smaller on a percentage basis than for the Non-Residential Program. However, the average connected thermostat cooling load reduction, as a percent, is larger for the Quasi-Residential (39.5%) than the Non-Residential program (27%). The load shape for quasi-residential sites is visibly distinctive and indicative of highly correlated site loads across sites managed by a few customers. Though aggregate load reductions are 1.0%, reductions are 39.5% of cooling load per connected thermostat.

Figure 11: ACSDA Quasi-Residential Summary for Average Event

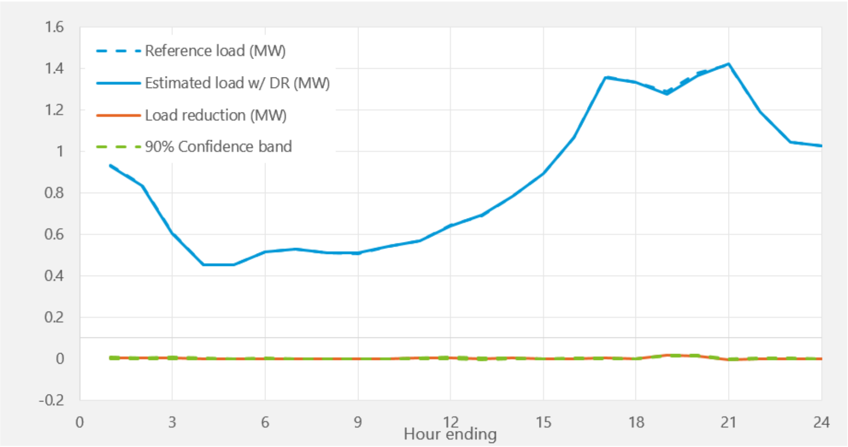
Update menus

Table 1: Menu options

Program	ACSDA (quasi-res)
Type of result	Aggregate
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	1,097
Total installed thermostats	1,173
Total connected thermostats	26
Percent of thermostats connected	2%
Avg load reduction 6PM-8PM	0.01
% Load reduction 6PM-8PM	1.0%



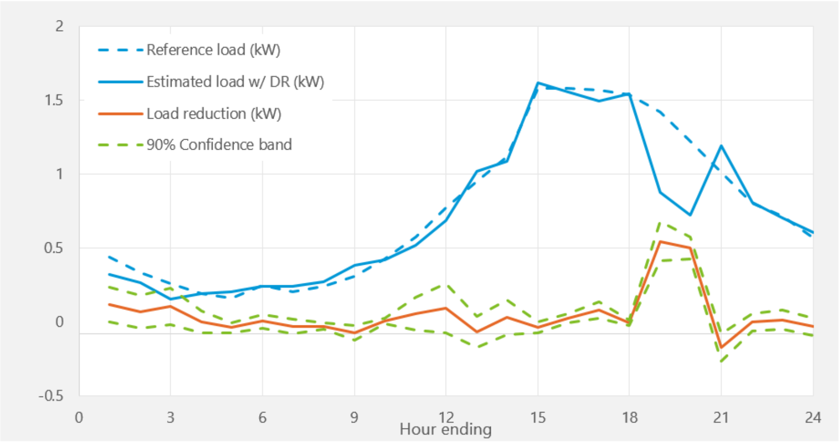
Update menus

Table 1: Menu options

Program	ACSDA (quasi-res)
Type of result	Average Connected Thermostat (Cooling load)
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	1,097
Total installed thermostats	1,173
Total connected thermostats	26
Percent of thermostats connected	2%
Avg load reduction 6PM-8PM	0.52
% Load reduction 6PM-8PM	39.5%



4.4 EX ANTE LOAD IMPACTS

A key objective of the 2019 evaluation is to quantify the relationship between demand reductions, temperature, and hour of day. Ex ante impacts are estimated load reductions as a function of weather conditions, time of day, and forecasted changes in enrollment. By design, they reflect planning conditions defined by normal (1-in-2) and extreme (1-in-10) peak demand weather conditions. The historical load patterns and performance during actual events are used the reductions for a standardized set of weather conditions.

At a fundamental level, the process of estimating ex ante impacts included five main steps:

1. Estimate the relationship between cooling load per thermostat (absent DR) and weather by hour of day
2. Estimate the relationship between cooling load percent reduction, temperature, and hours into an event using historical event data
3. Predict cooling loads and percent reductions for 1-in-2 and 1-in-10 weather year conditions
4. Combine the loads and percent reductions to estimate impacts per connected thermostat
5. Incorporate the enrollment/device forecast and device connectivity forecast

4.4.1 RELATIONSHIP OF CUSTOMER LOADS AND PERCENT REDUCTIONS TO WEATHER

Figure 12 summarizes the relationship between weather for commercial customers with commercial thermostats on CPP rates. Figure 13 does the same for ACSDA customers (excluding quasi-residential). Only days when the smart thermostat resources were not dispatched are included. Overall, energy demand and discretionary load increases with hotter weather.

These figures also provide an estimate for typical cooling loads for commercial thermostat sites by assessing how whole building loads per thermostat vary with temperature (left panel). The baseload is estimated by the load on cooling neutral days (max daily temperatures around 65 degrees, e.g. blue line in left panel). Net cooling loads (right panel) are total loads for each weather bin minus the baseload. Note that hotter temperature bands were available for plotting for ACSDA devices which skew less heavily toward the Coastal zone than do devices on dispatchable rates.

Even on days in the 90-93 max daily temperature band—typical for events—average whole building load per thermostat for CPPTD devices is about 3.3 kW during the typical 2-6 pm CPP event window, but cooling loads are only 33% of this, or about 1.1 kW per thermostat. On days with 90-93 max daily temperature average cooling load per thermostat for non-residential ACSDA devices is about 1.0 kW during the 1 pm to 6 pm period that counts towards resource adequacy requirements—ACSDA events are typically called later in the day but can be called anytime from 12pm to 9pm.

Because impacts are directly driven by connected thermostats controlling cooling loads, ex ante impacts were estimated as a function of cooling loads on a per thermostat basis.

Figure 12: Weather Sensitivity of CPPTD Program Participant Loads

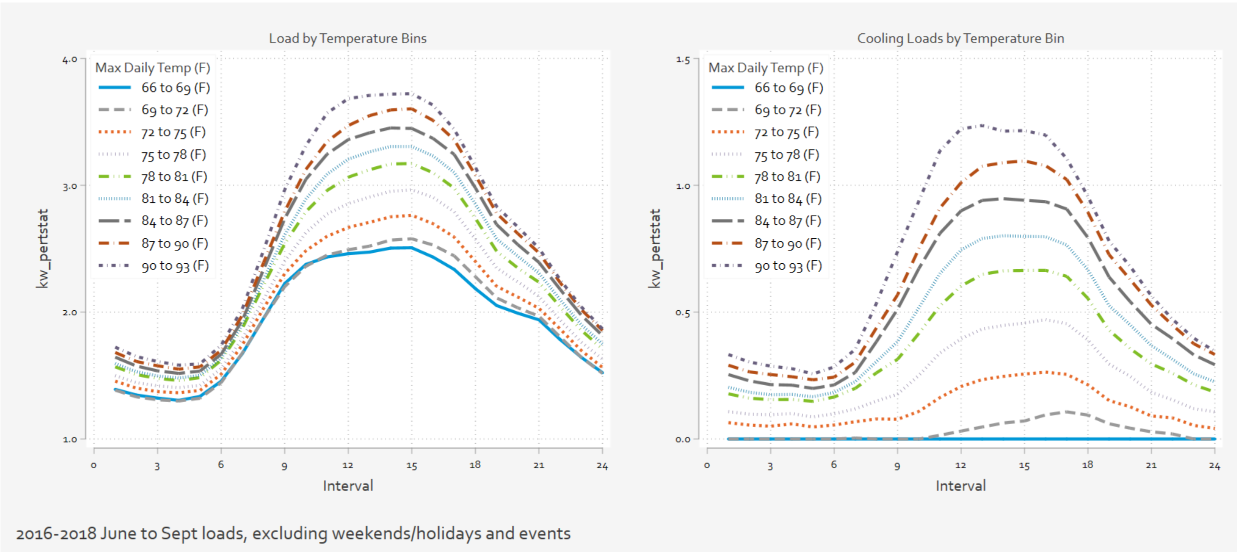


Figure 13: Weather Sensitivity of ACSDA Non-residential Program Participant Loads

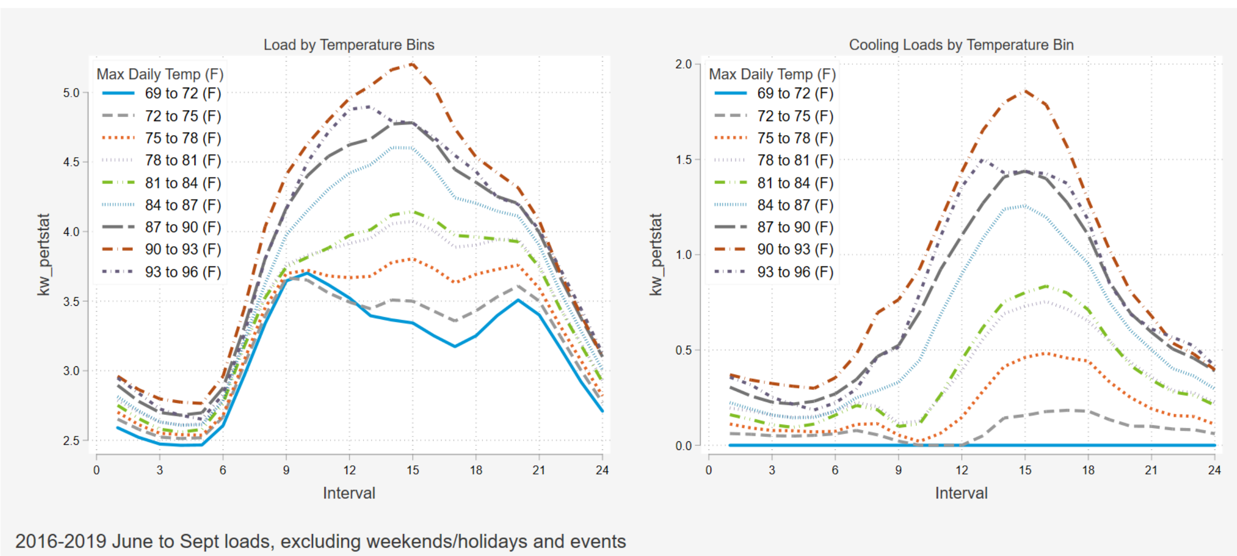
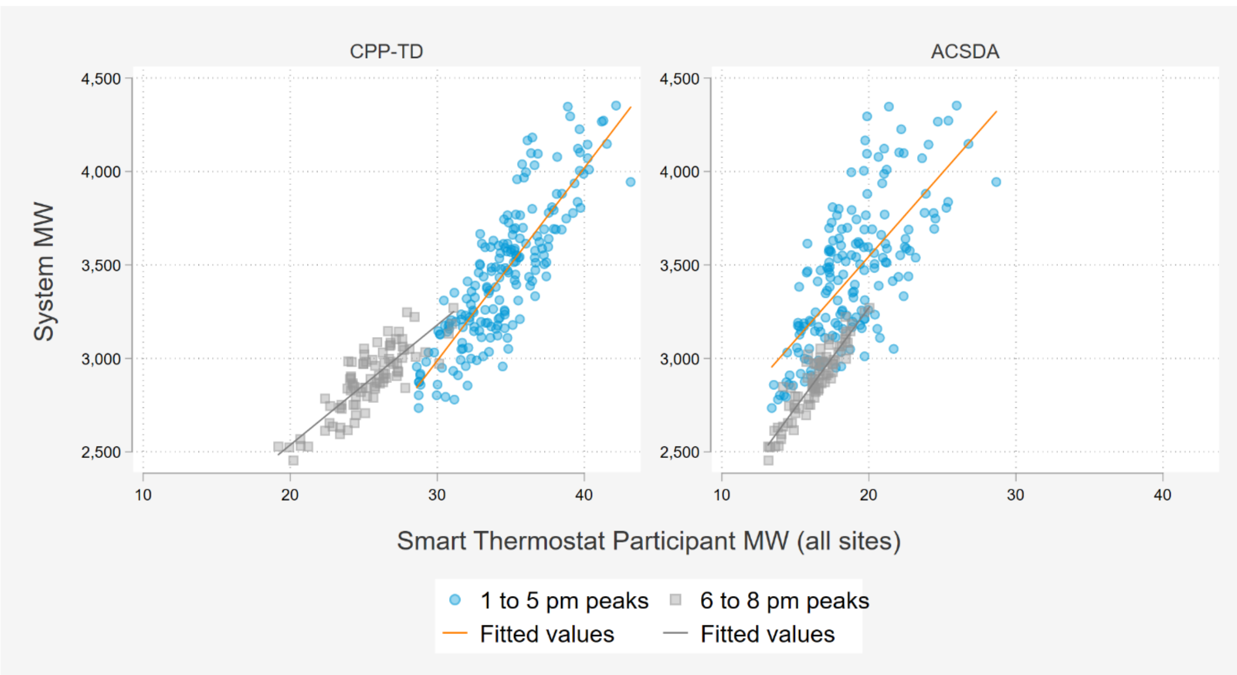


Figure 14 shows the relationship between aggregate loads for Technology Deployment sites and SDG&E daily peak loads. Daily peaks that occurred before 5pm (typically at 4 or 5pm) are shown in blue and those that occurred later are shown in grey. The patterns are quite different for Technology Deployment sites on CPP rates and those on ACSDA. In particular, sites enrolled on ACSDA have much higher loads on days with the highest system peaks, which also tend to occur earlier in the day. This is notable given that most ACSDA events in PY2019 were called in the evening when loads are much lower.

Daily peaks that occur later in the day (after 5pm) are smaller in magnitude and occur on days where maximum daily temperatures are about 5 to 10 degrees cooler than days with earlier peaks. Not surprisingly, smart thermostat participants use more power when it is extremely hot and contribute to peak demand, which drives the need for additional generation, transmission, and distribution infrastructure. Because cooling loads are a major driver of SDG&E peaks, if managed, they can reduce the need to build additional infrastructure to accommodate additional peak load. Because more discretionary load is in use during peaking conditions, reductions from commercial thermostats can be larger precisely when resources are needed most.

Figure 14: Commercial Thermostat Customer Loads During System Daily Peaks



Because the commercial thermostats are dispatched automatically for events, the main driver of differences in ex ante impacts are differences in loads. In 2016 and 2017, three weekday events were called and the event days and windows were common across Technology Deployment sites regardless of whether they were on CPP rates. These historical impacts along with those from the program specific events called in 2018 were included in the ex ante model estimation. The percent change in energy use was estimate for each of the ex post segments defined in Table 9 and applied to 1-in-2 and 1-in-10 weather year customer loads.

Figure 15 and Figure 16 show hourly event percent reductions for historical weekday events as a function of hourly temperatures for sites on each Technology Deployment program. Reductions are largely positive in magnitude, a handful are near zero (and not statistically significant) and few are negative, indicating an increase in load. For the CPPTD programs the positive relationship between temperature and load reductions is clear. In contrast, for ACSDA programs there are many event hours with non-significant impacts called during hours where temperatures did not surpass 80 degrees. Though events were historically called from ACSDA for sites not on dispatchable rates (and now on ACSDA), the bulk of historical impact observations for ACSDA sites comes from the seventeen events called in 2018. Given the weak temperature relationship and overall small impacts historically, ex ante impacts for ACSDA programs will also quite low even for planning conditions earlier in the day and for higher temperature.

Figure 15: 2016-2018 CPPTD Hourly Reductions and Temperatures

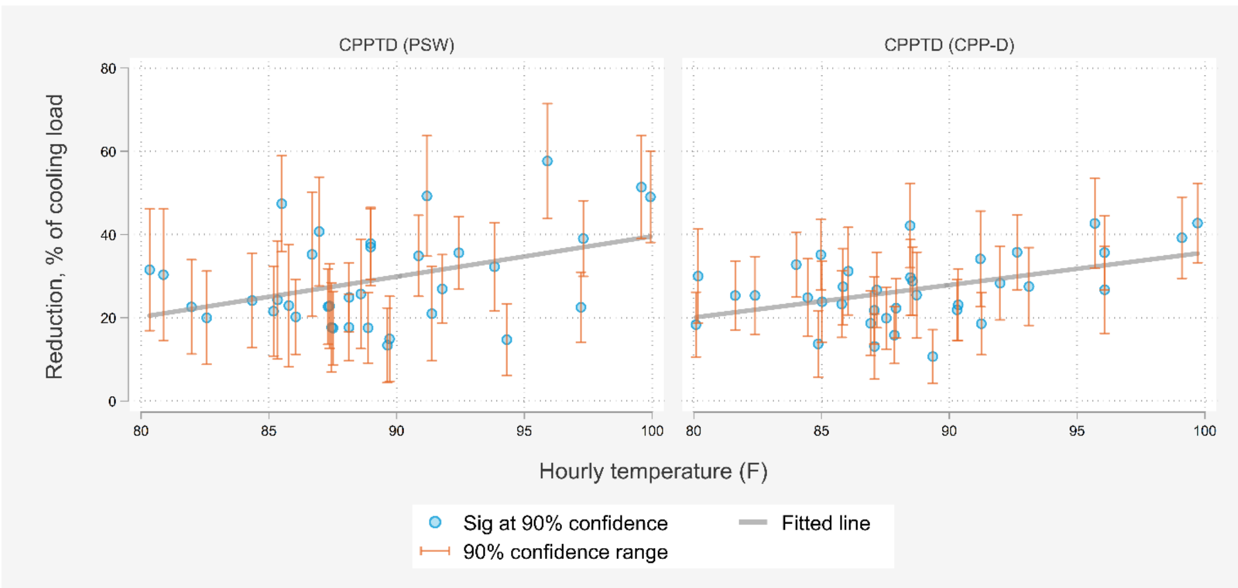
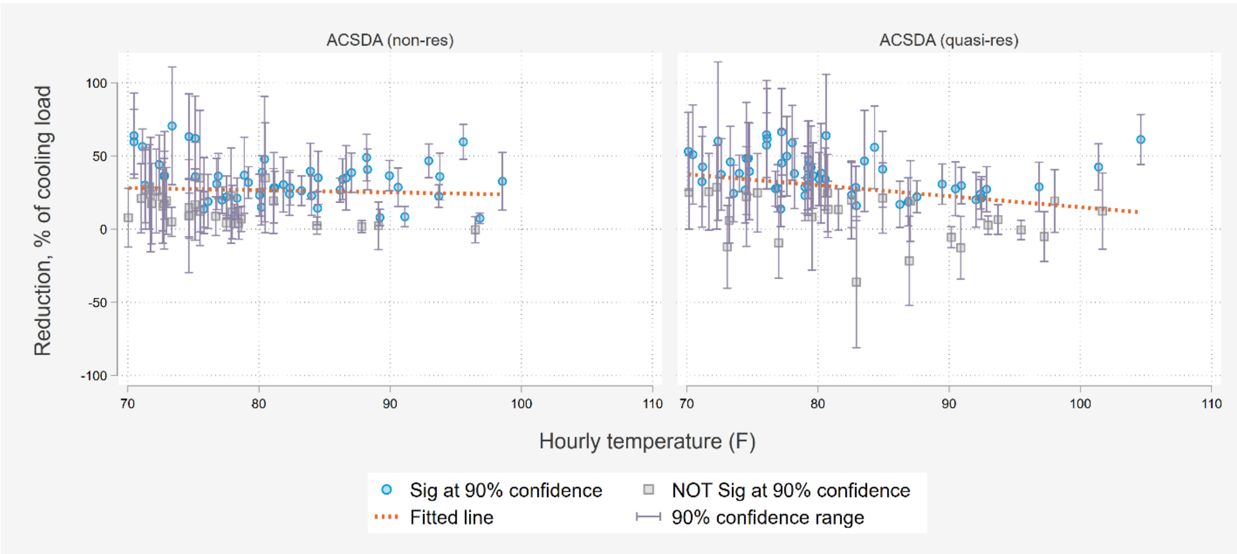


Figure 16: 2016-2019 ACSDA Hourly Reductions and Temperatures



4.4.2 Ex Ante Load Impacts

Table 16 summarizes the ex ante demand reduction capability by forecast year for 1-in-2 SDG&E weather planning conditions across all four Technology Deployment programs. The tables reflect dispatchable demand reductions available from 4 pm to 9 pm on August monthly peaking conditions. They align with the planning conditions used for resource adequacy attribution. They incorporate an enrollment forecast developed by SDG&E reflecting moderate growth in enrollment for sites on dispatchable rates. The enrollment forecast also incorporates declines in device connectivity in line with the historical average discussed at the beginning of this chapter. Ultimately, forecasted ex ante load reductions reflect load reductions delivered by connected devices among enrolled sites. Reductions are a function of the number of enrolled sites, the connectivity rate over time for installed devices, and the estimated load reduction per connected device.

Table 16: Non-residential Smart Thermostat Portfolio Impacts for 1-in-2 August Monthly Peak Day

Year	CPP-TD		ACSDA		Total
	PSW	CPP-D	Non-Res	Quasi-Res	
2019	0.08	0.22	0.74	0.00	1.05
2020	0.06	0.17	0.87	0.00	1.10
2021	0.05	0.12	0.98	0.00	1.14
2022	0.03	0.08	1.07	0.00	1.18
2023	0.02	0.06	0.90	0.00	0.98
2024	0.02	0.04	0.76	0.00	0.81
2025	0.01	0.02	0.64	0.00	0.67
2026	0.01	0.01	0.54	0.00	0.55
2027	0.00	0.00	0.45	0.00	0.46

Year	CPP-TD		ACSDA		Total
	PSW	CPP-D	Non-Res	Quasi-Res	
2028	0.00	0.00	0.38	0.00	0.38
2029	0.00	0.00	0.32	0.00	0.32
2030	0.00	0.00	0.27	0.00	0.27

Table 17 and Table 18 summarize the ex ante demand reduction capability by forecast year for different planning conditions, respectively, for sites on dispatchable rates (CPP-TD) and those that are not (ACSDA). The tables reflect dispatchable demand reductions available from 4 pm to 9 pm on August monthly peaking conditions for 1-in-2 and 1-in-10 weather conditions. They align with the planning conditions used for resource adequacy attribution. The enrollment forecast for the number of enrolled sites was developed by SDG&E was also applied to the counts of installed thermostats and shows moderate increases in the number of thermostats over time. The number of thermostats connected reflects the decline in connectivity observed historically and overlays this decline on the total population of installed thermostats. Impacts are a function of connected thermostats and therefore also decline over time.

Table 17: CPP-TD Portfolio Impacts for August Monthly Peak Day

Year	Sites	Tstats installed	Tstats connected	CAISO		SDG&E	
				1-in-2	1-in-10	1-in-2	1-in-10
2019	1,744	10,583	4,617	0.32	0.30	0.30	0.37
2020	1,677	10,105	3,472	0.24	0.23	0.23	0.28
2021	1,611	9,626	2,507	0.17	0.16	0.16	0.20
2022	1,544	9,148	1,687	0.11	0.11	0.11	0.13
2023	1,544	9,148	1,216	0.08	0.08	0.08	0.10
2024	1,544	9,148	838	0.06	0.05	0.05	0.07
2025	1,544	9,148	535	0.04	0.03	0.03	0.04
2026	1,544	9,148	291	0.02	0.02	0.02	0.02
2027	1,544	9,148	96	0.01	0.00	0.00	0.01
2028	1,544	9,148	19	0.00	0.00	0.00	0.00
2029	1,544	9,148	0	0.00	0.00	0.00	0.00
2030	1,544	9,148	0	0.00	0.00	0.00	0.00

Table 18: ACSDA Portfolio Impacts for August Monthly Peak Day

Year	Sites	Tstats installed	Tstats connected	CAISO		SDG&E	
				1-in-2	1-in-10	1-in-2	1-in-10
2019	1,524	7,412	3,028	0.77	0.76	0.75	0.83
2020	1,592	8,459	3,592	0.90	0.89	0.87	0.97
2021	1,660	9,506	4,069	1.01	1.00	0.98	1.08
2022	1,728	10,553	4,471	1.10	1.09	1.07	1.18
2023	1,728	10,553	3,764	0.93	0.92	0.90	1.00
2024	1,728	10,553	3,170	0.78	0.77	0.76	0.84
2025	1,728	10,553	2,669	0.66	0.65	0.64	0.71
2026	1,728	10,553	2,248	0.55	0.55	0.54	0.60
2027	1,728	10,553	1,893	0.47	0.46	0.45	0.50
2028	1,728	10,553	1,594	0.39	0.39	0.38	0.42
2029	1,728	10,553	1,343	0.33	0.33	0.32	0.36
2030	1,728	10,553	1,131	0.28	0.28	0.27	0.30

4.4.3 Comparison of Ex Post And Ex Ante Load Impacts

Table 19 compares the demand reductions from 2018 events to the PY 2019 reductions expected for the 1-in-2 weather conditions used for planning. Results are shown for the 4 to 9 pm resource adequacy window. Because there were no CPP events called in 2019, ex ante impacts are built using 2018 ex post impacts and enrollment forecasts from 2019. In 2018, the most recent year when CPP events were called, CPPTD customers delivered 2.37 MW during the dispatch period of 2 pm to 6 pm and 1.90 MW during the 4 to 9 pm resource adequacy window, which extends three hours beyond the CPP dispatch window, ex post reductions are much lower because they include three hours with no reductions, from 6 to 9 pm. Ex ante impacts for the resource adequacy window are lower than the corresponding ex post impacts. This is in part because ex ante temperatures for 1-in-2 weather conditions shown here are two degrees lower than for the events called in 2018 (ex post). Ex post results also reflect a changing mix of connected devices over the course of the summer and the unique hourly temperature profiles of each event, whereas ex ante impacts assume a fixed number of connected devices and weather for a single peak day.

Table 19: CPPTD Comparison of Ex Post and Ex Ante Load Impacts for 2019

Result Type	Day Type and Period	Sites	Tstats connected	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)
Ex Post Avg. Weekday (PY2018 Results)	Event Period (2pm to 6pm)	1,776	5,670	38.01	2.37	6.2%	90.9
	Resource Adequacy Period (4 to 9pm)	1,776	5,670	33.07	0.79	2.4%	90.9
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	1,744	4,617	35.78	0.30	0.9%	90.1
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	1,744	4,617	36.07	0.32	0.9%	89.7

Table 20 makes a similar comparison for ACSDA programs. An important difference is that ex post impacts are shown on average only across events with average temperature surpassing 70 F. Excluding the cooler events makes for a more meaningful comparison with ex ante results. In 2019, ACSDA customers delivered 0.57 MW during the typical dispatch period of 6 pm to 8 pm. However, because thermostat resources were largely only dispatched for two hours during the five-hour window, ex post reductions during the 4 to 9 pm resource adequacy window were lower (0.15 MW). In contrast, ex ante reference loads and impacts are greater for the 4 to 9 pm window, mostly because they assume five hours of dispatch. In addition, temperatures were over two degrees higher for 1-in-2 planning conditions than for the PY 2019 events. Further, it is important to note that percent reductions for ACSDA were relatively low and there is a greater degree of uncertainty with small percentage impacts. As with the CPPTD programs, ex post results also reflect a changing mix of connected devices over the course of the summer and the unique hourly temperature profiles of each event, whereas ex ante impacts assume a fixed number of connected devices and weather for a single peak day.

Table 20: ACSDA Comparison of Ex Post and Ex Ante Load Impacts for 2019

Result Type	Day Type and Period	Sites	Tstats connected	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)
Ex Post Avg. Weekday**	Event Period (6pm to 8pm)	1,452	2,980	18.71	0.57	3.0%	86.7
	Resource Adequacy Period (4 to 9pm)	1,452	2,980	18.64	0.15	0.8%	86.7
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	1,524	3,028	24.70	0.75	3.0%	89.4
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	1,524	3,028	24.94	0.77	3.1%	89.3

*Table shows portfolio impacts. To avoid double counting, it excludes commercial thermostats and customers dually enrolled in other DR programs.
**For comparability to ex ante, only includes events with average event temperature above 70F

5 CONCLUSIONS AND RECOMMENDATIONS

The two different interventions – CPP-TOU and commercial thermostats – each delivered statistically significant demand reduction. But there is room for improvement. The recommendations below may not be currently funded, and costs need to be considered alongside other research and program priorities. For clarity, we present the recommendations for technology deployment programs and critical peak pricing separately.

5.1 TECHNOLOGY DEPLOYMENT RECOMMENDATIONS

- **If possible, avoid bidding sites that lack connected thermostats into the CAISO markets.** Sites with loads that cannot be controlled or dispatched do not deliver any detectable demand reduction. They simply dilute the demand reductions and make them harder to detect.

- **Test different ways to nudge customers with disconnected thermostats to reconnect them.** Only connected thermostats deliver reductions and roughly half of installed thermostats are now disconnected. Without an intervention, a larger share of those devices will become disconnected as more time elapses. In specific, we recommend randomized control trial four different groups:

  - Control (n = 100)
  - Postcard or letter reminder (n = 100)
  - Postcard or letter reminder + follow up phone call (n = 100)
  - Postcard or letter reminder + incentive (n =100)
  - Postcard or letter reminder + follow up phone call + incentive (n=100)

  This will allow SDG&E to quantify how well different methods work at getting customers to reconnect and assess their cost-effectiveness.

5.2 SMALL COMMERCIAL CRITICAL PEAK PRICING RECOMMENDATIONS

Since no CPP events were called in PY 2019, the following recommendations from PY 2018 could not be reviewed. However, they will likely still merit exploration in subsequent program years.

- **Assess if additional communications encouraging response improve reductions using randomized controlled trials.** The magnitude of demand reductions during events is small on a percentage basis, about 1%, providing ample room to improve reductions. Additional communications require resources and their effectiveness at improving price response is unknown. Because of the potential, however, we recommend testing the effectiveness of more education regarding event response. It is critical, however, for the test to be implemented using randomized control trials, so it is possible to assess if the communications had any impact on price response.

- **Notification rates for small CPP can be improved further.** Customers elect whether or not to sign up for notifications and by which channels they receive notification. Because notification is closely linked to response, additional efforts to improve notification rates are recommended. From 2016 to 2017, the notification rate improved from under 25% to 44%. Because many customers have multiple sites (and don't always sign up all sites), customers for roughly 60% sites received notification. Despite the improvement, there is further room to improve notifications. Notification rate remained largely unchanged in PY 2018.

APPENDIX

A. PANEL REGRESSION MODELS WITH MULTIPLE CONTROLS

Panel regressions with multiple control groups were used as the primary method for estimating load impacts for PY 2019 impacts for ACSDA. The approach is implemented on a time series of individual customer loads. It relies on multiple non-equivalent control sites that did not experience the intervention, plus weather and day characteristics, to estimate the counterfactual. The panel model estimates a counterfactual load using weather and loads for the matched control sites. A separate model is estimated for each hour of day. Reductions are the difference between the participant and counterfactual loads with a panel model, one should observe:

- Very similar energy use patterns for participant and counterfactual loads when the intervention is not in place.
- A change in demand patterns for customers who are dispatched or subject to time varying prices, but no similar change for the counterfactual load.
- The timing of the change should coincide with the introduction of intervention.

The use of a panel model allows for incorporation of multiple control sites and does not rely on finding a single ideal match. The equation for the model is presented below. A separate model was estimated for each intervention and hour of the day for each of the analysis segments identified as part of the evaluation plan. Pre and post event terms (single hour with two-hour buffer) were added to the Technology Deployment models to implement the same calibration for these load control programs.

$$kW_{i,t} = \mathrm{a} + \mathrm{b} \cdot kW\_1 - kW\_5_i + \sum_{n=1}^{max} \mathrm{c}_n \cdot Event_n + \mathrm{d} \cdot CDH_{i,t} + \delta_t + \varepsilon_{i,t}$$

Where:

$\mathrm{kW}_{\mathrm{i,t}}$	Is the usage for each individual customer and time period
a	Is the model intercept
b	Loads for the five most closely matched control sites based on Euclidean distance matching. They did not experience the treatment and are weighted based on their predictive power.
c	Controls for differences between event and non-event days
d	Is the parameter for weather sensitivity of loads
Event	Is a binary variable indicating if day is an event. Separate variables are used for each event so impacts are estimated for each event. It has a value of zero on event-like proxy days. The five closest non-event days were included as proxy days for each event. Separate proxy days were selected for each event using Euclidean distance matching.
δ_{t}	Represents time effects for each time period. This accounts for observed and unobserved factors that vary by time but affect all customers equally.
$\varepsilon_{\mathrm{i,t}}$	Represents the error term for each individual customer and time period.